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SALINITY IMPACT ON DIATOM POPULATIONS OF TWO WESTERN LAKES

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ABSTRACT

The diatom flora and several physical factors of two lakes (Sodergreen and West Carroll) in the semiarid region of southeastern Wyoming were studied. The two lakes proved to be both physiochemically and floristically quite different. Sodergreen Lake tested low in total dissolved solids (195 ppm, autumn, 1968) and West Carroll Lake tested relatively high in total dissolved solids (3,899 ppm, autumn, 1968). Seasonal (autumn, winter and spring) changes in epiphytic flora from both lakes were studied and predominant species were identified. Several other occasional collections of planktonic and epilithic diatoms are included in the analysis. Data from these studies indicate that the sharp differences in chemical composition of the two lakes is clearly reflected in the differences in the diatom taxa (74 species) of the lakes.

INTRODUCTION

The study of lacustrine diatoms has been of interest to phycologists for years; yet, the number of floristic and community studies concerning saline waters, exclusive of oceans and their marshes, has been minimal. The objective of the present study was to make a preliminary investigation of the diatom flora of two lakes in the Laramie Basin, Wyoming, comparing the flora of one lake containing relatively low concentrations of dissolved solids with the other containing higher.

Several investigators in the United States have studied the diatoms in western lakes, some of which were saline. Young (1924) included diatom lists in his investigation of the biota in Devil's Lake, North Dakota. The saline lakes of Saskatchewan, Canada, physiochemically similar to those of Wyoming, were studied quite extensively by Rawson (1960) and Rawson and Moore (1944). These studies related the distribution of diatoms to biological and physical factors. The diatom flora of the saline (sodium chloride) lakes of Lower Grand Coulee, Washington,

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has been studied with respect to attached forms and their periodicity by Anderson (1954, 1958) and Castenholz (1960). Other reports of diatoms in western lakes were made by Curtis (1889), Elmore (1921), Malony (1943) and Van Landingham (1966).

In Wyoming a limited number of algal and limnological surveys have been carried out but no extensive work involving diatoms has been done. Reports have been made on the algae of Albany County and the adjacent Medicine Bow Mountain areas of Wyoming by Nelson (1900), Giles (1933), and Miller (1933). Dolenc (1967) reported 35 different diatom taxa in his algal survey of the Green River. A few diatoms of uncertain affinity have been reported in limnological surveys by King (1951), Skinner (1952), Millis (1956), and Wilson (1966). The latter reports have been concerned with various fresh and saline lakes of the state.

Salinity is defined by Riley and Chester (1971) as "the weight in grammes of the dissolved inorganic matter in 1 kg of sea water after all bromide and iodide have been replaced by the equivalent amount of chloride, and all carbonate converted to oxide." Yet, when associating salinity specifically to inland water, Hutchinson (1957) regarded it as the concentration of all the ionic constituents present. A more definitive categorization of inland fresh and saline waters is made by Hesse et al. (1962) when he specifies saline waters as those with a minimum salt content of 300 ppm. They are formed in climates where there is a high rate of evaporation associated with no outflow; consequently, there is an accumulation of salts leached from surrounding drainage basins. These conditions are common in the arid and semiarid climate of western United States where sulfate or chloride may be the most abundant anions in solution.

DESCRIPTION OF THE STUDY AREA

Two lakes in Wyoming, Sodergreen (N 41° 9' 40"; W 105° 55' 30") and West Carroll (N 41° 21' 40"; W 105° 44' 27"), were chosen for study (Fig. 1). Both are similar with respect to morphometric features (Table 1) yet different with respect to total dissolved solids (e.g., salinity). Based on total dissolved solids seldom exceeding 300 ppm (Hesse, 1962), Sodergreen Lake is classified as fresh-water and West Carroll Lake saline. Even though both lakes are located in the Laramie Basin at an altitude of approximately 2,155 m and have an annual mean precipitation of 28.3 cm, Sodergreen Lake maintains its freshness by the continual addition of fresh-water from the Big Laramie River.

MATERIALS AND METHODS

Samples for this study were gathered during the autumn, winter, and spring from as many locations possible (19 during study period) in order to collect specimens from planktonic, epiphytic, and epilithic habitats. Epipelic diatoms (Round, 1957) were not collected since apparatus was not available to sample this community. Autumn collections were made from 28 September 1968 to 11 October 1968, winter collections from 25 January 1969 to 14 February 1969, and spring collections between 12 April 1969 and 14 April 1969. The planktonic habitat was

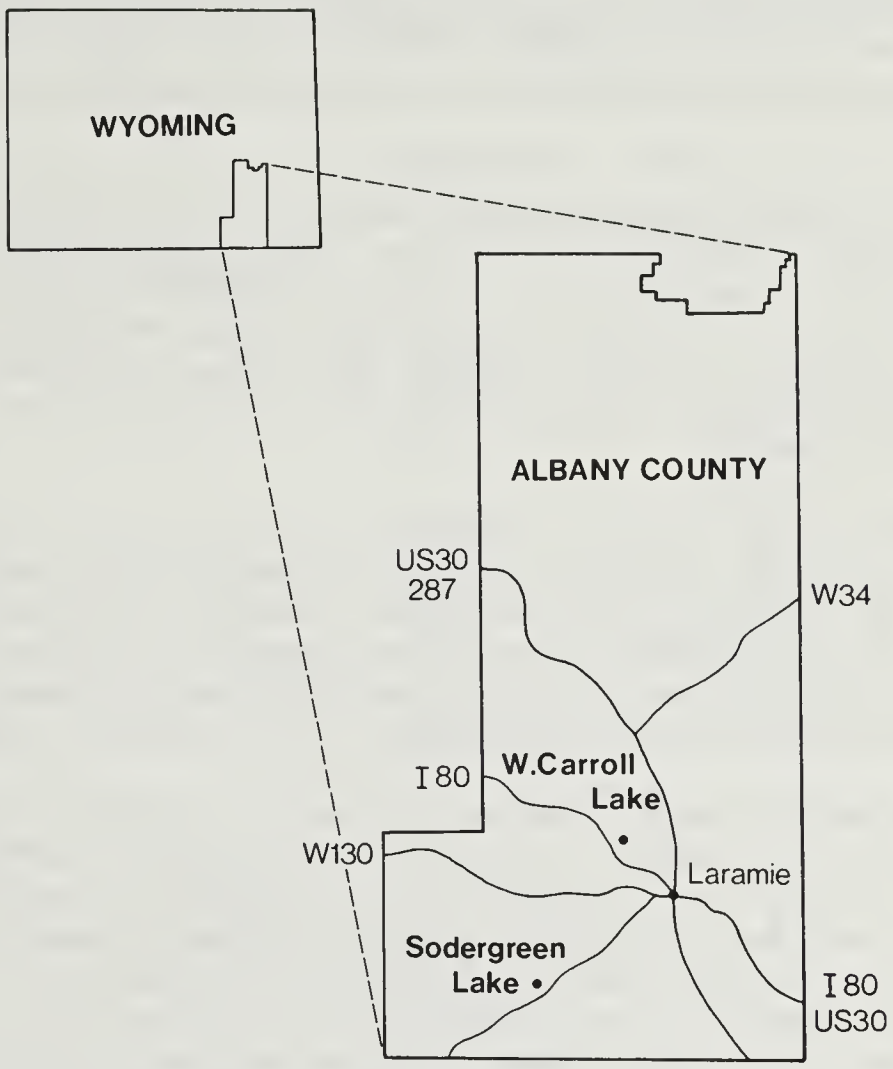

Figure 1. Map showing the location of Sodergreen and West Carroll Lakes, Albany County, Wyoming.

Table 1. Morphometric data for Sodergreen and West Carroll Lakes, Albany County, Wyoming.

Features	Sodergreen	West Carroll
Altitude (m)	2252.5	2130.0
Length (m)	610.0	800.4
Width (m)	488.0	430.5
Area (ha)	28.9	21.1
Mean width (m)	474.2	258.6
Maximum depth (m)	9.5	7.5
Mean depth (m)	4.2	4.0
Length of shore line (m)	2029.9	1948.8

sampled with a #25 bolting cloth plankton net. Epiphytic forms were removed from dead and living plant debris by hand squeezing the vegetation and collecting the droppings. Rocks, boat ramps, fence posts, and dam buttresses were scraped with a dull pocket knife to collect epilithic diatoms.

Upon returning to the laboratory all collections were placed in a 250 ml beaker with 100 ml of conc. HNO_3 and boiled rapidly on a hot plate under a fume hood until contents had nearly evaporated. The resultant material was then processed through several changes of distilled water to return the pH to neutral and remove oxidized by-products. Permanent slides were prepared according to methods described in Patrick and Reimer (1966).

Chemical analysis of the water was made once (25 January 1969) during the study period; conductivity and pH were each measured once during the autumn (11 October 1968), winter (25 January 1969), and spring (12 April 1969) by the state chemical laboratory (Table 2). Water temperature was taken in the field on the same days with a standard Academy Centigrade Thermometer and these data appear in Table 2.

Two methods were selected to study the diatom flora of Sodergreen and West Carroll Lakes. Epiphytic diatoms were counted on slides prepared from seasonal (autumn, winter, spring) collections to determine the most abundant forms from this particular community. Secondly, all collections in each lake were pooled from planktonic, epiphytic, and epilithic communities and composite collection slides were prepared for comparison. This was accomplished by uniting 10 ml of diatom suspension from each storage container into a single composite collection for the planktonic, epiphytic, and epilithic habitats. Counting was done by subdividing the diatom strewn cover slips into quarters and randomly positioning the microscope in each of the four sections. The first 25 diatoms in each quarter were counted and were identified to either specific or varietal rank for a total count of 100 individuals per slide.

RESULTS

A survey of the analyzed electrolytes (Table 2) indicate that Sodergreen Lake is a relatively soft water lake whereas West Carroll Lake is a hard water lake, particularly rich in sulfates. Magnesium sulfate and sodium sulfate are predominant salts in the lake. The data indicate that the hydrogen-ion concentration of the two lakes was similar and that there was little change throughout the study period. Conductivity in Sodergreen Lake increased from autumn through spring; whereas, in West Carroll Lake it increased in the winter but decreased to the fall value in the last sampling in the spring.

A primary aim of the investigation was the establishment of a preliminary list (Table 3) of representative diatoms from two high plateau, prairie lakes, Sodergreen and West Carroll. Subsequently, each diatom was ecologically ranked according to its tolerance of salt in the environment. Kolbe (1927) established an ecological classification system whereby diatoms can be classified by their salinity (halobien)

Table 2. Results of physical analysis of water from Sodergreen and West Carroll Lakes, Albany County, Wyoming.[1]

Factors	Sodergreen	West Carroll
Chemical analysis in ppm (Winter)		
Boron	0.03	0.76
Calcium	29.5	64.0
Magnesium	6.4	311.7
Sodium	4.3	520.0
Potassium	1.3	12.0
Carbonate	0.0	30.0
Bicarbonate	97.6	460.0
Sulfate	28.8	2,030.0
Chloride	3.5	106.0
Nitrate	0.0	0.0
Seasonal pH		
Autumn	8.2	8.6
Winter	7.8	8.5
Spring	8.3	8.5
Seasonal Conductivity (EC x 10^6 at 25^oC)		
Autumn	195	3,899
Winter	218	4,040
Spring	231	3,870
Seasonal water temperature in degrees centigrade		
Autumn	10	13
Winter	0	0
Spring	6	5

[1] Seasonal analysis of physical characteristics was made on the following dates: Fall, 11 October 1968; Winter, 25 January 1969; Spring, 12 April 1969.

tolerance. Each taxon identified in this study was placed into a halobien spectrum category, modified by Hustedt (1957), from various ecological data presented in Hustedt (1957, 1961) and Foged (1953, 1954, 1958, 1959, 1966, 1972).

Since the seasonal phase of the investigation was concerned with study of all collections taken in the epiphytic habitat throughout the study period, Table 3 presents the taxa and Figs. 2 and 3 illustrate the relative abundance of predominant species. In this aspect of the study there was a total of 34 taxa reported (Column B, Table 3) with 6 species common to the epiphytes of both lakes, Cocconeis placentula var. lineata, Cyclotella meneghiniana, Diatoma tenue var. elongatum, Epithemia sorex, E. zebra var. porcellus, and Rhopalodia gibba.

Comparative lists (Column A, Table 3) of resultant flora from the three habitats indicate that the two lakes are very heterogeneous in their floral composition. In this aspect of the study 65 different taxa were collected with only 8 species occurring in both lakes, Cyclotella meneghiniana, Diatoma tenue var. elongatum, Rhoicosphenia curvata, Cymbella affinis, Epithemia sorex, E. zebra var. porcellus, E. zebra var. saxonica, and Nitzschia hungarica.

Planktonic Flora

An early spring collection in Sodergreen Lake contained a bloom of Synedra ulna var. danica and Melosira granulata var. angustissima. A large autumn bloom of the more commonly epiphytic diatom Epithemia sorex pervaded in West Carroll Lake since it also dominated plankton samples. Other predominant planktonic taxa from the comparative study include Cymatopleura solea and Nitzschia vermicularis in Sodergreen Lake, and Gomphonema olivaceum var. calcarea, Mastogloia smithii, and Rhopalodia gibba in phytoplankton of West Carroll Lake.

Epiphytic Flora

Predominant autumn epiphytes from West Carroll Lake include Rhopalodia gibba, Epithemia sorex, Diatoma tenue var. elongatum, and Mastogloia smithii. Epiphytic flora developing in the spring were dominated by Rhopalodia gibba and Epithemia zebra var. porcellus. Cocconeis placentula var. lineata was the most abundant early fall epiphyte on the phanerogams of Sodergreen Lake. When similar phanerogams in Sodergreen Lake were obtained from below several centimeters of ice in late January, a new flora existed consisting of Nitzschia dissipata, Diatoma tenue var. elongatum, and Amphora perpusilla. Soon after the ice cover was gone a bloom of Diatoma tenue var. elongatum and Navicula salinarum var. intermedia dominated the epiphytic flora. An interesting observation pertaining to the dominant seasonal epiphytic flora (Figs. 2 and 3) is that under nearly identical climatic conditions Diatoma tenue var. elongatum achieved winter bloom proportions in both the saline and fresh-water lakes.

Epilithic Flora

Spring collections from small rocks and other debris in West

Table 3. Diatom taxa identified in the comparative habitat and seasonal epiphytic phases of the study accompanied by its Halobien rank.

Species	A Comparative[1] Habitat			B Seasonal[2] Epiphytic	C Halobien[3] Ranking
	Pl*	Ep	El		
Melosira granulata v. angustissima Mull.	S	S	S	S	OI
Cyclotella meneghiniana Kütz.	B		WC	B	OH
Diatoma tenue Ag.		WC		WC	OH
D. tenue v. elongatum Lyngb.	B	B	B	B	OH
D. vulgare v. ovalis (Fricke) Hust.				WC	OI
Meridion circulare v. constrictum (Ralfs) V. H.		S			OI
Fragilaria bicapitata Mayer			S		OI
F. brevistriata Grun.	S				OI
F. capucina Desm.		S			OI
F. capucina v. mesolepta Rabh.	S				OI
F. construens v. binodis (Ehr.) Grun.	S				OI
F. leptosauron (Ehr.) Hust.			S	S	OI
F. pinnata Ehr.	S		S		OI
F. pinnata v. lancettula (Schum.) Hust.			S		OI
F. vaucheriae (Kütz.) Peters.	S	S			OI
Synedra capitata Ehr.	S				OI
S. delicatissima W. Sm.	S				?
S. fasciculata v. truncata (Grev.) Patr.				WC	OH
S. parasitica (W. Sm.) Hust.	S		S	S	OI
S. parasitica v. subconstricta (Grun.) Hust.		S	S		OI
Synedra pulchella Ralfs ex Kütz.				WC	EM
S. tabulata (Ag.) Kütz.	WC	WC	WC	WC	EM
S. ulna (Nitz.) Ehr.	S				OI
S. ulna v. chaseana Thomas		S			?
S. ulna v. danica (Kütz.) Grun.	S	S		S	OI

Table 3. Continued.

		A		B	C
S. ulna v. ramesi (Hérib.) Hust.			S		OI
Cocconeis pediculus Ehr.	S	S	S		OI
C. placentula v. lineata (Ehr.) V. H.	S	S	S	B	OI
Achanthes lanceolata v. dubia Grun.		S			OI
Rhoicosphenia curvata (Kütz.) Grun. ex Rabh.	WC		S	WC	OI
Mastogloia smithii Thwaites ex W. Sm.	WC	WC		WC	EM
M. smithii v. lacustris Grun.				WC	OH
Gyrosigma attenuatum (Kütz.) Rabh.	S				OI
Diploneis puella (Schum.) Cl.		S	S		OI
Stauroneis anceps f. linearis (Ehr.) Hust.		S			OI
Navicula cuspidata Kütz.		WC	WC		OI
N. cuspidata v. Heribaudi Peragallo			S		OI
N. graciloides Mayer	S				H
N. menisculus v. upsaliensis (Grun.) Grun.				S	?
N. oblong (Kütz.) Kütz.		WC			OI
N. salinarum v. intermedia (Grun.) Cl.		S	S	S	OI
N. tripunctata (Mull.) Bory			WC		OI
N. viridula v. linearis Hust.		S		S	OI
Amphiprora alata Kütz.		WC	WC		EM
Gomphonema constrictum Ehr.		S		S	OI
G. olivacium (Lyngbye) Kütz.		WC	WC	S	OI
G. olivacium v. calcarea Cl.	WC	WC	WC		OI
G. parvulum Kütz.		S			OI
Amphora perpusilla Grun.	S	S	S	S	OI
A. veneta Kütz.		WC		WC	OI
Cymbella affinis Kütz.	WC	B		WC	OI
C. prostrata (Berk.) Cleve			S		OI
C. prostrata v. auerswaldii (Rabh.) Reim.		S	S	S	?
C. sinuata Greg.	S				OI
Epithemia sorex Kütz.	WC	B	B	B	OI
E. turgida (Ehr.) Kütz.			S		OI
E. zebra v. porcellus (Kütz.) Grun.	WC	WC	S	B	OI
E. zebra v. saxonica (Kütz.) Grun.	WC	S			OI

Table 3. Continued.

		A		B	C
Rhopalodia gibba (Ehr.) O. Mull.	WC	WC	WC	B	OI
R. gibba v. ventricosa (Ehr.) Grun.		WC	WC		OI
Nitzschia acicularis (Kütz.) W. Sm.				S	OI
N. admissa Hust.				S	OI
N. amphibia Grun.	S				OI
N. dissipata (Kütz.) Grun.		S		S	OI
N. hungarica Grun.		WC	B		EM
N. palea (Kütz.) W. Sm.				WC	OI
N. spectabilis (Ehr.) Ralfs	S				EM
N. tryblionella v. debilis (Arnott) May.				S	OH
Nitzschia vermicularis (Kütz.) Grun.	S				OI
Cymatopleura solea (Bréb.) W. Sm.	S	S		S	OI
C. solea v. regula (Ehr.) Grun.	S				OI
Surirella biseriata v. bifrons (Ehr.) Hust.	S				OI
S. brightwellii W. Sm.	WC				?
S. ovalis Bréb.			WC	WC	EM

[1]Specific lake(s) taxon collected in comparative phase of the study.
S=Sodergreen Lake, WC=West Carroll Lake, B=Both lakes.
*Pl=Planktonic, Ep=Epiphytic, El=Epilithic.

[2]Lake abbreviations as above.

[3]Halobien Key: EP=Polyhalobe, EM=Mesohalobe, OH=Halophil, OI=Indifferent, H=Halophobe, ?=Unknown, based on Hustedt's (1957) modification of Kolbe's (1927) halobien system.

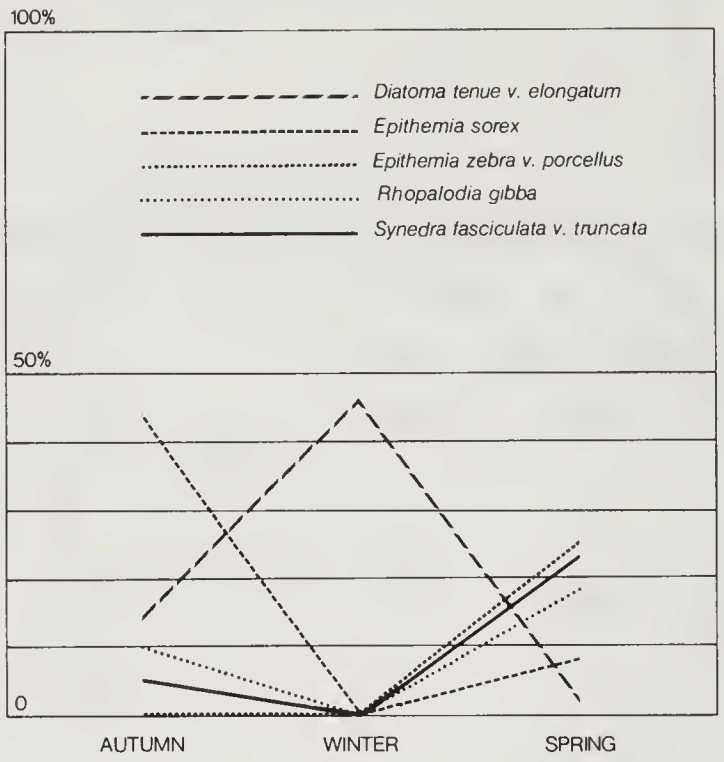

Figure 2. Relative abundance (%) of dominant epiphytic diatom species in Sodergreen Lake, Albany County, Wyoming.

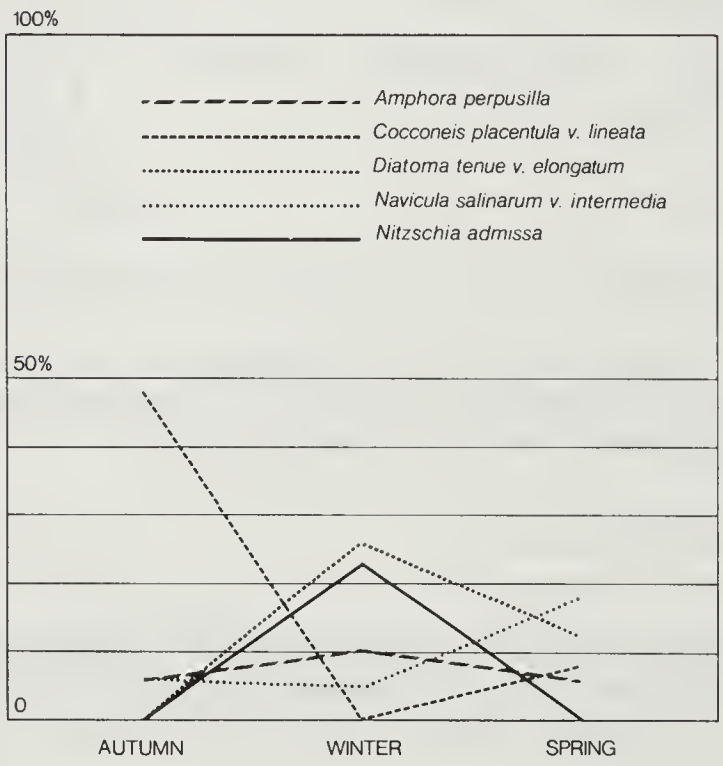

Figure 3. Relative abundance (%) of dominant epiphytic diatom species in West Carroll Lake, Albany County, Wyoming.

Carroll Lake were dominated by Surirella ovalis, commonly classed as an epipelic diatom. Other taxa colonizing this lake substratum included Nitzschia hungarica, Navicula tripunctata, and Gomphonema olivaceum var. calcarea. A common epilithic species in Sodergreen Lake throughout the study period, and reaching bloom proportions during winter was Amphora perpusilla. During the fall the epilithic community of Sodergreen Lake was dominated by two diatoms from other communities, Epithemia sorex-an epiphyte and Melosira granulata var. angustissima-a planker.

When examining the combined studies in view of the halobien spectrum (Hustedt, 1957), 21% of the taxa in the saline lake (West Carroll) are ecologically classified as mesohalobien (diatoms that live in a saline environment of from 5-25‰) and 18% are classified as halophilic (diatoms that can withstand a salinity less than 5‰), (Column C, Table 3). This is in sharp contrast with the diatom flora of the fresh-water lake (Sodergreen), whereby only 4% of the species encountered are classified as mesohalobien. On the other end of the halobien spectrum, halophobe species (diatoms that cannot tolerate the presence of salt) are completely absent from West Carroll Lake, whereas Sodergreen Lake contained 2% of these intolerant forms.

DISCUSSION

The data presented suggest that the diatom flora of two geographically similar lakes is different, and this difference is a result of salinity tolerant taxa in the lake with a high concentration of total dissolved solids. This difference can be further supported by surveying other diatom reports where taxa and water chemistry are given. Such reports are as follows: a fresh-water (based on conductivity less than 300 ppm) raised bog (Reimer, 1961) contained 23% of the fresh-water species reported here and 16% of the saline water species reported here; Northern Alaskan fresh-water lakes (Patrick and Freese, 1961) contained 34% of the fresh-water and 20% of the saline water species; a eutrophic fresh-water lake (Stoermer, 1963) contained 56% of the fresh-water and 46% of the saline water species; a salt marsh (Drum and Webber, 1966) contained 13% of the fresh-water species and 20% of the saline water species; and dry saline lake beds in Nevada (Van Landingham, 1966) contained 11% of the fresh-water species and 20% of the saline water species.

Although numerous environmental factors influence an organism's development and existence, distribution is a greater result of a few limiting factors that cannot be tolerated by a species. As it can be seen in Table 3, 55 taxa (74%) of the 74 total taxa in the study are ecologically ranked as "indifferent" to the presence of salt in their environment. It is the remaining taxa that are tolerant or intolerant of salt in their environment that determine the floral composition of these two distinctly different diatom communities.

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POTENTIAL OF THE THREADFIN SHAD AS A FORAGE FISH IN MIDWESTERN POWER COOLING RESERVOIRS[1/]

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ABSTRACT

Threadfin shad (Dorosoma petenense) were successfully introduced into Southern Illinois Lake of Egypt in spring 1971. Adult shad overwintered for five years in the warm water discharge of a 100 megawatt fossil fuel power plant. No serious problems due to the shad introduction were encountered. Before the introduction, few white crappie (Pomoxis annularis) reached 200 g and the major diet of these crappie appeared to be insects. Within six years after introduction, a strong crappie fishery developed on the lake. After six years, the average calculated weights of white crappie were 2, 38, 100, 199, 546 and 896 g, at annulus 1-6, respectively.

White crappie between 150 to 240 mm total length fed heavily on threadfin shad only in the fall. White crappie larger than 240 mm total length utilized threadfin shad throughout spring, summer and fall.

INTRODUCTION

A particular problem in the management of crappie (Pomoxis spp.) populations has been slow growth rates resulting in a small percentage of the population attaining harvestable size. Crawley (1954) suggested three possible factors responsible for stunting of white crappie (P. annularis): (1) population

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density, (2) heredity, and (3) food supply. Rutledge and Barron (1972) reviewed the literature concerning these factors and concluded that formations of dominant year classes, producing either severe intra- or inter-specific competition, was responsible for crappie stunting.

New lakes and reservoirs are characterized by rapidly expanding fish populations with fast growth rates. Within several years, growth rates decrease and fishing success declines. Lewis (1967) summarized several studies which indicate that reduction in prey vulnerability was the principal factor in declining growth rates of predator populations. He suggested that the prey species responsible for the rapid growth rate are highly vulnerable to predation and thus are eliminated from the population.

In midwestern lakes the primary forage fish that is not eliminated is the gizzard shad (Dorosoma cepedianum), but because of its rapid growth rate it provides only a limited amount of forage to crappie and a high standing crop of non-vulnerable gizzard shad often develops. In southern lakes threadfin shad (D. petenense) have been reported to be a desirable forage fish (Myhr 1971, Range 1973, and Stevens 1959). Such findings have resulted in recommendations for stocking the threadfin shad where slow-growing crappie populations exist (Goodson 1966). However, since the threadfin shad dies at water temperatures below 10 C, they are found in Illinois streams only during the spring and fall. The warm water discharge created by the operation of fossil fuel electrical generating plants offers a unique opportunity to establish warm water stenothermic fishes in midwestern states.

The objectives of this study were to determine if an overwintering threadfin shad population could be established in a southern Illinois power cooling reservoir, to monitor the effect of this population on the existing white crappie population, and to investigate possible problems encountered due to the fall die off of the threadfin shad.

METHODS AND MATERIALS

Adult threadfin shad were stocked into Lake of Egypt and the growth rates of the shad and white crappie were monitored. In the spring of 1971, fifteen hundred adult threadfin shad that averaged 61 mm in total length were captured by seining on their spawning run in Lake Hamilton, Arkansas, and trucked to Illinois. Twelve hundred of these fish were released into Lake of Egypt, a 931-ha artificial impoundment located in Williamson County, Illinois. Lake of Egypt contains a typical warm water fish population including the gizzard shad. Southern Illinois Power Company operates three fossil fuel electrical generating units having a total capacity of 100 megawatts on Lake of

Egypt. The warm water discharge from these units keeps the impoundment's extreme northern portion ice-free throughout the winter.

Threadfin shad were sampled periodically from 1971 through 1975 with meter nets, gill nets (1.26, 1.90, 2.53, 3.80, 6.40 bar mesh), electroshocker, and from the revolving screens on the power plant intake. White crappie were sampled periodically by fishing, electroshocking and gill netting from 1969 through 1976. Since three sampling methods were employed, it is unlikely that any size class was missed. Total length to the nearest mm was recorded from representative samples of the threadfin shad. Scale samples were taken from the largest adult shad for age and growth analysis. All crappie were measured to the nearest mm total length and weighed to the nearest gram. Scale samples were taken for age and growth analyses. Stomach contents from all crappie were examined and classified into threadfin shad, other fish, or insects.

RESULTS

Threadfin shad have overwintered in the limited warm water discharge of the reservoir for five winters. Because of their thermal requirement of water temperatures 10 C or above, the shad are limited to an area of approximately 1.2 ha immediately below the warm water discharge pipe during January and February. Since warm water from the discharge pipe layers on top of the cold water in most of the 1.2 ha area, the potential threadfin shad brood stock population must remain in approximately 19,000 m^3 of water for several months. During the winter numerous largemouth bass (Micropterus salmoides) and crappie move into the warm water and feed on the shad. Electrofishing and gill netting indicate that most of the threadfin shad disperse from the warm water area in the spring as soon as the lake temperature reaches 13 to 14 C.

The maximum length attained by the threadfin shad was greater the first year than it was in any of the next four years (Table 1). However, in all five years, numerous 30-35 mm young-of-the-year shad were captured in meter nets during October.

An attempt was made to age white crappie collected from Lake of Egypt a year before and for three years after the introduction of threadfin shad. Scales from 562 fish 125 to 255 mm (31-208 g) displayed two to five annuli with an almost complete overlap of age groups within this size class. Only 26 crappie were heavier than 180 g and 2 were heavier than 200 g. It was concluded that the crappie in this population were clustered in this size range. If older fish were in the population they could not be detected by scale analysis or

Table 1. Maximum total length in mm of threadfin shad in fall samples from Lake of Egypt

Year sampled	Year class				
	1971	1972	1973	1974	1975
1971	114(216)[1/]				
1972	132(18)	66(153)			
1973		104(12)	68(200)		
1974			106(7)	68(150)	
1975				144(25)	96(112)

[1/]Number in parenthesis = sample size

length frequency analysis. It was impossible to obtain an average length and weight for each age group; therefore, increased spacing between the circuli was used as an indication of increased growth rate. When fish, especially small fish, are growing rapidly, there is usually considerable spacing between the circuli (Lagler et al. 1962, p. 119). Scales from fish less than 190 mm (160 g) did not appear to exhibit marked increased growth within the first three years after the shad introduction. Fish larger than 190 mm (160 g) appeared to be growing rapidly based on these criteria.

Stomach content analysis of 161 white crappie (20-208 g) taken in 1971 before the build up of a dense threadfin shad population indicate that the primary diet of all sizes of white crappie was Chaeoborus larvae. After the introduction of threadfin shad, stomach contents of crappie larger than 180 g included threadfin shad throughout the summer and fall. Further, there were only traces of Chaeoborus larvae in these larger crappie. During the summer, crappie less than 160 g continued to feed primarily on Chaeoborus. However, in the fall these smaller crappie also utilized threadfin shad (Table 2).

Age and growth analysis of white crappie collected in November 1976 did not display the clustering effect noted in the early part of the study. The average calculated weights of white crappie were 2, 37, 97, 183, 513 and 881 g at annulus 1-6, respectively (Table 3). The growth of white crappie at age group I was slower in Lake of Egypt than in other lakes at a similar latitude that do not contain threadfin shad. Growth rates of age group II-III white crappie were similar, whereas age groups IV-VI usually exhibited much faster growth rates (Table 4).

The percent frequency of occurrence of food items found in the stomachs of white crappie collected in November 1976 again demonstrated a major change in feeding habits with crappie size (Table 5). The stomach contents of white crappie

Table 2. Frequency of occurrence of preponderant food items, expressed as percent in the diet of white crappie that contained food from Lake of Egypt

Food item	Month of collection and weight range of white crappie in g									
	April 1971		July 1971		October 1971		July 1972		October 1974	
	20-160	180+	20-160	180+	20-160	180+	20-160	180+	20-160	180+
Fish										
threadfin shad	-	-	-	100(4)[1/]	60(57)	100(7)	-	100(6)	51(63)	90(20)
gizzard shad or other fish	-	10(10)	-	25(4)	-	14(7)	-	-	-	10(20)
Insects										
chironomidae	100(151)	100(10)	100(88)	0(4)	80(57)	0(7)	100(74)	0(6)	65(63)	5(20)

[1/] Number of fish in parentheses.

Table 3. Calculated average total length (mm) of white crappie sampled November 1976 from Lake of Egypt, Illinois

Age group	Year class	No.	Calculated average total length (mm) at each annulus[1/]					
			1	2	3	4	5	6
I	1976	9	74					
II	1975	109	57	149				
III	1974	263	64	147	201			
IV	1973	66	71	169	219	247		
V	1972	7	96	212	265	310	344	
VI	1971	3	103	218	298	345	374	413
Total number			457	448	339	76	10	3
Average length			64	152	207	257	353	413
Length increment			64	88	55	50	96	60
Standard deviation			12.2	22.0	22.0	35.5	24.1	9.7
Range in length			45-113	105-229	146-262	193-347	306-384	402-421
Calculated weight (g)[2/]			2	38	100	199	546	896

[1/] Since there was no significant difference (0.01) in the length and weight of male and female crappie, the sexes were combined.

[2/] $\text{Log } W = -5.3460 + 3.1725 \text{ Lob TL} \quad R^2 = 0.988$

Table 4. Comparison of white crappie growth rates in Lake of Egypt and in selected midwestern lakes that do not contain threadfin shad

Impoundment	Calculated average total length (mm) at each annulus						
	1	2	3	4	5	6	7
Lake of Egypt[1/] (present study)	64	152	207	257	353	413	
Dale Hollow, TN (Range 1973)	80	152	189				
Horseshoe Lake, IL (Gunning 1954)	67	155	216	257	297	331	
Crab Orchard, IL (present study)	106	154	178	201	213	238	279
Red Haw, IA (Lewis 1950)	79	193	213	251	284	307	
Clear Lake, IA (Neal 1963)	71	145	185	208	234	272	323

[1/] Six years after threadfin shad stocking.

Table 5. Stomach contents of white crappie sampled November 1976 from Lake of Egypt, Illinois

TL size range (mm)	Avg. wt. (g)	Stomach contents: Empty no. (%)	Insects no. (%)	Fish[1/] no. (%)	Total no.
120-129	21	1 (25)	3 (75)	0 (0)	4
130-139	27	5 (16)	26 (84)	0 (0)	31
140-149	33	8 (24)	25 (76)	0 (0)	33
150-159	41	4 (40)	2 (20)	4 (40)	10
160-169	50	4 (33)	0 (0)	8 (67)	12
170-179	61	9 (45)	1 (5)	10 (50)	20
180-189	72	25 (40)	4 (6)	34 (54)	63
190-199	85	24 (32)	1 (1)	51 (67)	76
200-209	100	25 (40)	0 (0)	37 (60)	62
210-219	116	10 (33)	0 (0)	20 (67)	30
220-229	134	4 (27)	0 (0)	11 (73)	15
230-239	154	19 (56)	0 (0)	15 (44)	34
240-249	176	9 (53)	0 (0)	7 (47)	15
250-259	200	4 (27)	0 (0)	11 (73)	15
260-269	226	2 (22)	0 (0)	7 (78)	9
270-279	254	1 (25)	0 (0)	3 (75)	4
280-289	284	1 (25)	0 (0)	3 (75)	4

[1/] At least 95% of these were threadfin shad.

less than 150 mm total length consisted of Chaeoborus larvae and a few chironomid larvae. White crappie 150 mm total length (approximately 33 g) and greater fed basically on threadfin shad.

In addition to determining the effect of the threadfin shad introduction on the white crappie population, several potential problems due to the fall die off of threadfin shad were also monitored. The die off occurs over a several month period, and at no time during the five winters were large numbers of threadfin shad found washed upon the shoreline. At the time of the first die off (fall 1971), large numbers of threadfin shad were impinged on the self-cleaning intake screens at the power plant, resulting in a partial clogging of the screens. This clogging was attributed to three causes. First, spot lights which were used to illuminate the intake structure caused large numbers of the photosensitive threadfin shad to concentrate in the intake area. Secondly, the water jets used on the rotating screens were not correctly aligned to remove the impinged fish, thus fish remaining on the screens fell behind them. Thirdly, fish that were washed off the front of the screen by the water jets fell into a trough that emptied into the lake beside the intake structure. Thus the dead fish were recycled onto the screens. As these shad began to decay, fewer and fewer were knocked off the screens by the water jets. By turning off the spotlights on the intake structure, re-aligning the water jets, and placing a cage under the trough discharge, the clogging problem was eliminated during the next four years of winter die off, and no power plant operation problem was encountered because of this phenomenon.

DISCUSSION

The rapid growth rate of threadfin shad from the first spawn was probably due to their relatively low density as a consequence of the limited number of brood fish initially stocked. For the next three years the maximum length of age group 0 shad stabilized around 6.8 cm. This may indicate that the overwintering population remained relatively stable. The increased growth rate during 1975 may have been due to an unusually warm period in February 1975 when most of the shad appeared to have moved out of the warm water and were subsequently killed by the following freezing temperatures. Sixteen hours of intensive electroshocking in the warm water on four days in March yielded only 123 shad.

Even though 30 mm threadfin shad were present in Lake of Egypt during most of the summer, they were not eaten by crappie less than 160 g until the fall. It is possible that the shad were stressed from reduced water temperature in the fall and became highly vulnerable to predation. Crappie larger than 180 g utilized threadfin shad throughout the summer as well as in the fall. This differential feeding

behavior probably accounts for the fact that larger crappie exhibited a substantial increase in growth rate after threadfin shad were introduced, while smaller crappie did not. Even though white crappie between 150-240 mm total length appear to utilize threadfin shad only in the fall, this short feeding period on a fish diet may be very important in moving the fish to a size where they can feed on shad all summer.

As a result of the increased growth of the larger crappie, a desirable crappie fishery has developed on Lake of Egypt. Good quantitative creel census data are not available to support this subjective observation, but it is notable that one minnow dealer has increased his distribution of minnows to Lake of Egypt five fold over the last three years.

Even though the threadfin shad is usually considered to be a desirable forage fish, several researchers have reported that a high standing crop of overwintering threadfin shad has correlated with a low year-class or slow growth of young-of-the-year largemouth bass (von Geldern and Mitchell 1975). This is thought to be caused by competition for plankton between the larval largemouth bass and young-of-the-year threadfin shad. Since in midwestern waters the largemouth spawns before the threadfin shad, and even in power cooling reservoirs most of the adult threadfin shad winterkill, there is less chance of competition either directly or indirectly with the largemouth bass.

The warm water discharge has allowed threadfin shad to overwinter in Lake of Egypt for five years. During this time a desirable crappie fishery has developed. In addition, these overwintering shad can be used each spring to stock non-cooling lakes where complete winterkills of threadfin shad occur. Heidinger and Imboden (1975) have indicated that this is feasible at midwestern latitudes, since young-of-the-year shad spawn the same year. Thus, only a small number of adult fish need to be transferred to a new lake to create a dense forage population by late summer.

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RADIORESISTANCE AND OTHER ASPECTS OF *AUREOBASIDIUM PULLULANS* (DE BARY) GROWN AEROBICALLY AND UNDER NITROGEN.

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ABSTRACT

The radioresistance of the blastospores and chlamydospores of *Aureobasidium pullulans* (de Bary) grown in shake culture was increased by cultivation at constant pH and nitrogen tension and further enhanced by following this with aerobic growth conditions. The ultrastructure of the blastspore and chlamydospore grown under nitrogen and oxygen were compared. Changes of cell wall and mitochondria were evident. Studies of the composition of the aerobically produced pigment were made.

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INTRODUCTION

One of the most important representatives within a group of radio-resistant microorganisms is the yeastlike fungus Pullularia pullulans (de By.). Due to its polymorphic form, dependent upon growth conditions, it was isolated and described under some synonyms like Aureobasidium pullulans, Dematium pullulans, and Pullularia pullulans(3).

The nonspecific nutritional requirements of P. pullulans makes it a commonly and frequently encountered organism. Bauer (1) reported about its osmophilic character, being able to divide in saturated sugar solutions. Bender (2) and Cooke (3) described growth conditions and the formation of an extracellular polysaccharide which was extensively produced in media with glucose or sucrose, the amounts of which depend on the sugar concentration. Merdinger (10) studied their growth in high glucose concentrations and showed that trehalase was its main carbohydrase and that it has ability to grow over a broad pH range.

The present work investigated the survival of blastospores and chlamydospores after irradiation with ^{60}Co and describes the cytology of anaerobically and aerobically grown cells by electronmicroscopic techniques. Finally, some attempts were made to determine what relation pigment formation plays in the above.

MATERIALS AND METHODS

Pullularia pullulans, (NrrL YB-4515) a Danish strain, was cultivated on potato-dextrose agar pH 4.6 at 23°C. For investigative work the organism was grown in shaken cultures or in a pH static system in potato-dextrose broth (Difco). Shaken cultures were incubated for three weeks in a Brunswick Gyrotory shaker at 30°C (1000 ml Erlenmeyer flasks with 400 ml medium). The blastospores were harvested by centrifugation at 3000 rev/min and washed three times with 0.15 M phosphate buffer pH 7.0. The coated chlamydospores could be separated from the blastospores by decantation after centrifugation because they did not sediment at 3000 rev/min as the uncoated blastospores. Separated chlamydospores were then partially sedimented at 4000 rev/min.

Static Growth Conditions: A 14 liter Brunswick microfermentor, adapted with a Metrohm pH meter for automatic control of the pH to 4.6 and containing 12 liters of potato-dextrose media, was inoculated with 400 ml of a 12-hr-old suspension of P. pullulans. The system was held anaerobically by a flow rate of 2 liters per min of sterile nitrogen. After four days the unpigmented blastospores were harvested from 6 liters of medium by centrifugation. Aeration of the remaining 6 liters of medium was continued with a flow rate of 2 liters per min. After 1.5 hr of aeration cell material was collected from 3 liters of medium for study of ratio-resistance, while aeration of the remaining medium was continued for electronmicroscopic studies.

Irradiation: Irradiation experiments were carried out in a ^{60}Co source with a dose rate of 540,000 rad per hr at 20°C. Cells were suspended in 0.15 M phosphate buffer pH 7.0. After irradiation the suspension were diluted and plated on potato-dextrose agar. For every irradiation dose three plates with three dilutions were used. Every experiment was repeated three times. The sterile plastic Petri dishes were incubated at 30°C and after three days the colonies counted.

Electronmicroscopy: The ultrastructure of blastospores and chlamydospores was investigated, in the sections after embedding in epon and vestopal resin (1, 13), and with freeze etching method (12). Thin sections were produced with an automatic Reichert-Ultramicrotome. Glass knives were obtained with a LKB knife maker. Freeze-etched preparations were produced with Balzers instruments. After etching, the replicas were treated with sulfuric acid and Dakins solution to remove the remaining organic particles. After final washing with distilled water the copies of the broken cell surfaces were picked up on formvar coated grids. Electronmicroscopy was performed with a Siemens UM 60. Samples were taken at different times during both anaerobic and aerobic growth for the cytological investigations.

Pigment: Pigmented Cells were broken by homogenization with a Sorvall Omin-mixer by adding to each gram of cells 3 g of 0.1 mm glass beads and 3 ml of 0.1 M acetate buffer (pH 5.5). The pigment was recovered by centrifugation at 40,000 rev/min. The pigment was dialyzed exhaustively versus water and subjected to Molisch and Benedicts tests before and after 1 hr with hydrolysis 1 N HCl. Paper chromatograms were run ascendingly with Whatman #1 employing t-amyl alcohol:i-propanol:water:4:1:1.5; v:v:v, to identify hydrolysis products. Spots were detected using an ammoniacal silver nitrate spray.

RESULTS AND DISCUSSION

The survival curves of three-week-old blastospores and chlamydospores harvested from shaken cultures are different in their radioresistance at low doses (Fig. 1). Growth inhibition of chlamydospores (Curve A) appeared at 135 krad whereas the blastospores (Curve B) began to be affected at 220 krad. The LD_{99} was the same (650 krad) for both cell forms. The separated blastospores (Curve C) cultivated anaerobically at constant pH, were more resistant (LD_{99} 860 krad) than the three-week-old cells from shaken cultures. The resistance was enhanced (Curve D) when the anaerobically grown cells were further cultivated aerobically for 1.5 hr. The LD_{99} of these cells increased to 1.4 Mrad. Growth of cells was slow and pigment formation was suppressed for the 48 hr duration of anoxic conditions. But after four hours under oxygen the cells grew rapidly and

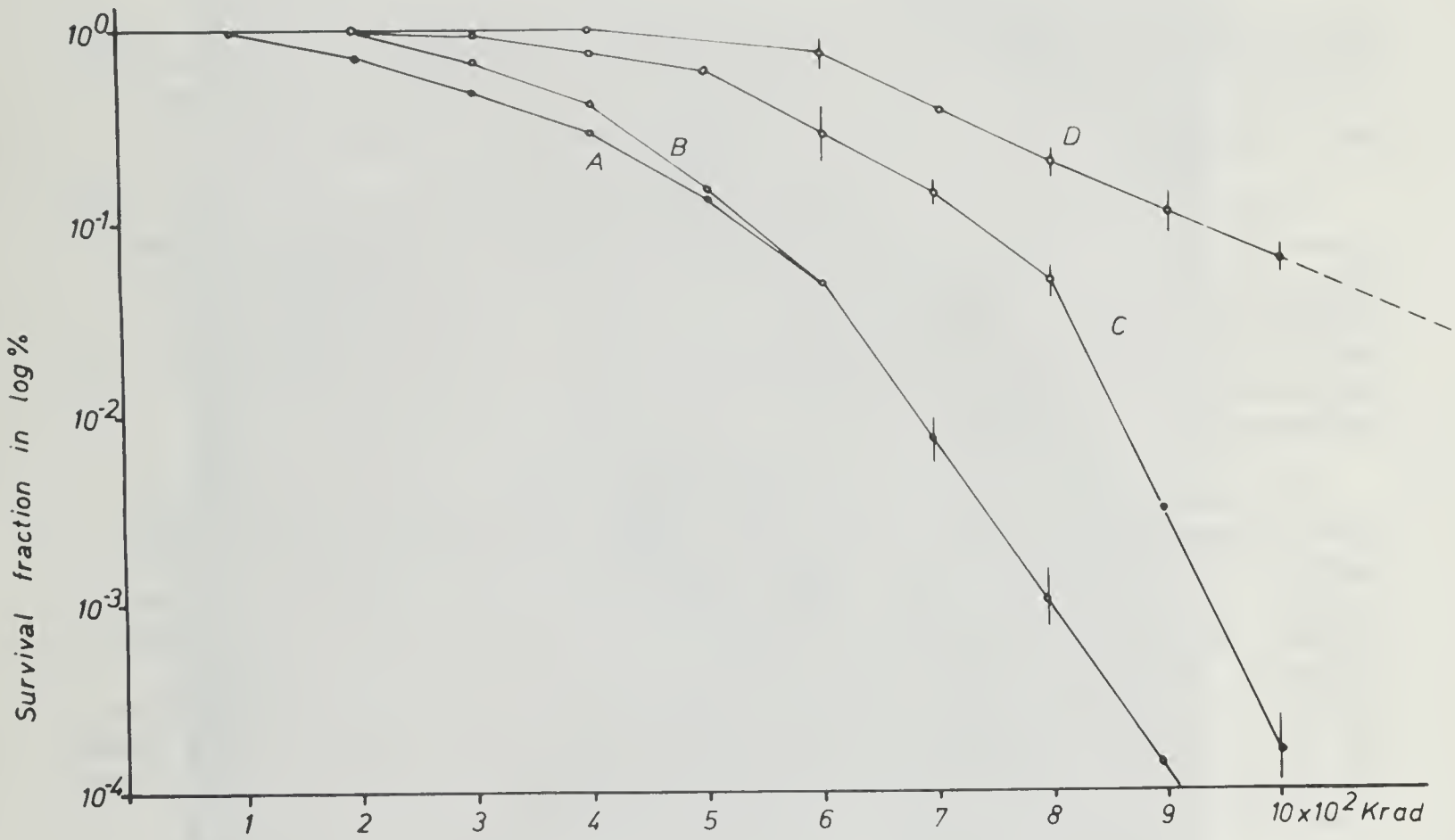

Fig. 1. The radioresistance of blastospores and chlamydospores of A. pullulans at low doses is illustrated in their survival curves. Curve A shows that inhibition of chlamydospores appeared at 135 Krad, while inhibition of the blastospores (Curve B) began at 220 Krad. Curve C shows blastospores grown under nitrogen and constant pH. Curve D shows blastospores grown as in Curve C but having 1.5 hr of aerobic growth prior to irradiation.

formed pigment suddenly. Preliminary attempts at characterizing the pigment of the aerobic cells has yielded the following findings. The pigment is most likely a macromolecule since it was sedimented at 40,000 rev/min and was not dialyzable after eight days. The isolated pigment gave a negative Benedict's but postive Molisch test. After acid hydrolysis the Benedict's test became positive for the neutralized hydrolysate. The color and amount of the pigment remained unchanged after the hydrolysis. Chromatograms of the concentrated hydrolysate showed that glucose was the only detectable monosaccharide in the system employed.

Neither the black pigment nor the coating of chlamydospores protected the cells from the effects of ionizing radiation since the nitrogen-grown cells lack these factors but are nevertheless more radioresistant than the coated and black-pigmented cells of a shake culture. Merdinger (10) previously reported the conditions for formation of pigment by A. pullulans, which seemed not to be identical with melanin, as suggested by Bender

et al. (2) and Durrell (6). Whether the carbohydrate, which is an integral part of the pigment is mono-, di-, or polysaccharide was still to be established.

Cytology of blastospores and chlamydospores: With plating tests it could be established that gas conditions during cultivation influenced survival of cells. Therefore it was of some interest to investigate and compare the ultrastructure of P. pullulans grown anaerobically and aerobically.

Cells grown under nitrogen atmosphere showed the absence of a distinct outer cell wall (Fig. 2) as compared to aerobically grown P. pullulans (Fig. 3) or as reported for the conidiospores and ascospores of Byssochlamys fulva (13). Where visible, the outer cell wall appeared as a small line with a density greater than normal. The fluffy particles surrounding the cell are not similar to the extracellular polysaccharide pullulan which is produced under oxygen conditions.

Nitrogen grown blastospores exhibited invaginations varying between short linear and large bent forms (Fig. 4). After aeration the plasmalemma of these aerated blastospores showed no invaginations or similar surface structures. This conversion of invaginated membranes to smooth-surface membranes seemed to occur within 4 h. Differences in the number and shape of the invaginations, which depended on the gas conditions during cultivation, were found in the present study. Moor and Muhlethaler (11) found a correlation between the age of yeast cells and the number of invaginations. No invaginations, or only those of slight degree, were found in young cells but they accumulated in older cells.

In some mitochondria (Fig. 5) the cristate are only small lines, and in some there is only a diffused zone, which may indicate the residue of the mitochondrial cristae. Comparing Figure 5, showing an early stage of growth under oxygen, to Figure 3 showing cells cultivated under oxygen for a longer period, we find that the number of hypertrophic mitochondria is approximately equal to the number of lipid bodies in the boated cells. The presence of lipid and its enhanced synthesis in aerated cultures may be an additional factor in the radioresistance of A. pullulans. With the progress of the culture all mitochondria may have changed to lipid bodies. That great changes in cell metabolism occur is also indicated by a fast increase in KOH consumption. Similarily with the activation of the cell metabolism the formation of pigment and pullulan start within a short time.

Acid production, as evaluated by consumption of KOH, occurred in a linear fashion under nitrogen growth conditions for 4 days but increased rapidly upon aeration. Bauer (1) found a relative independence of pH on the growth of A. pullulans. Greater radiosensitivity may be related to unfavorable growth conditions, to the decrease of the viability with age, and to deficiency of media and simultaneous accumulation of extracellular products especially organic acids which may act on cell growth and enzyme systems. It is assumed that the repair-enzyme systems may also be affected by long cultivation in shake culture. Serianni (14) found that the cells of Micrococcus radiodurans were more sensitive to x-rays in the logarithmic growth phase than in the stationary one. Contrariwise, the

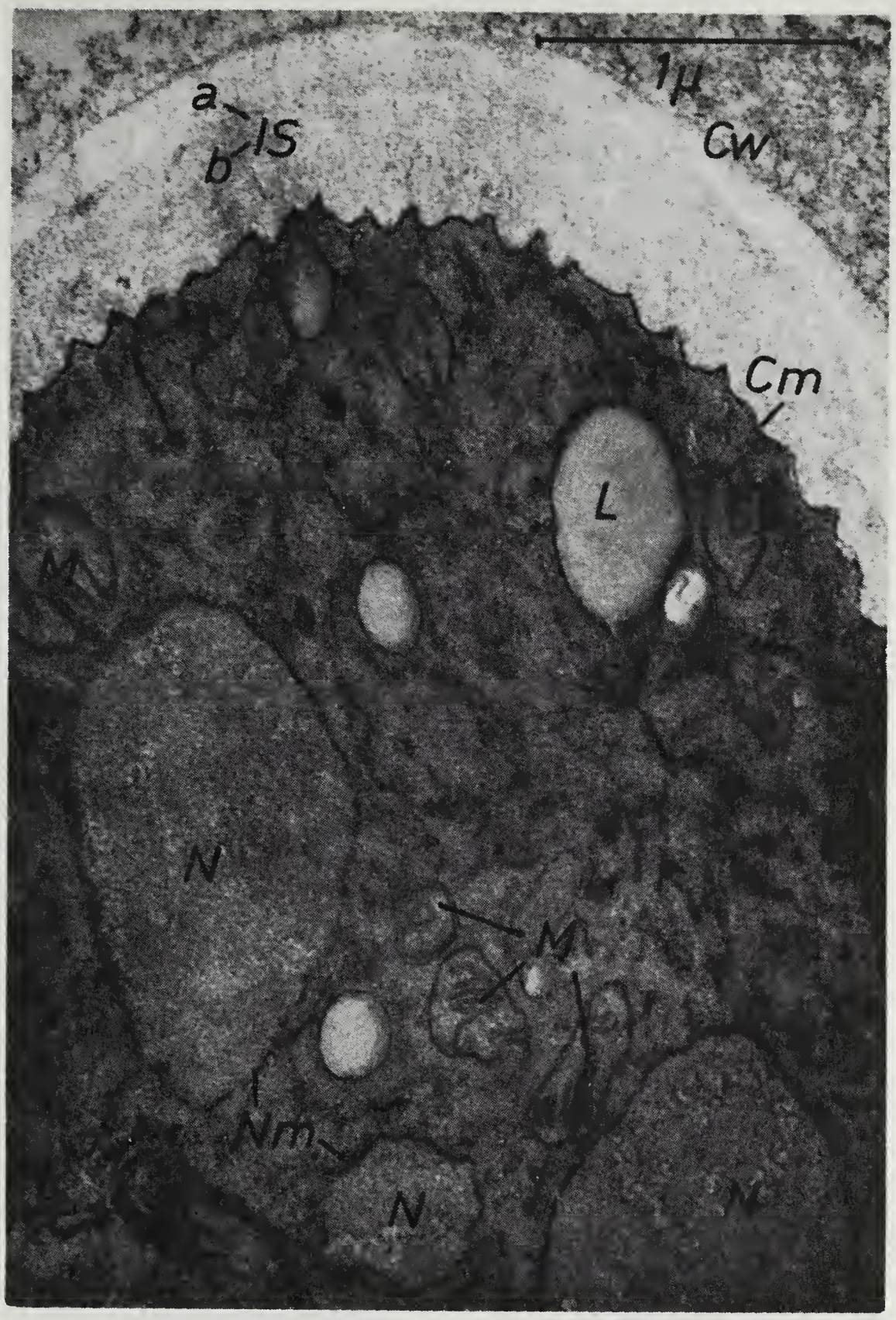

Fig. 2.* A blastospore of Aureobasidium pullulans showing three nuclei and a great number of mitochondria, perhaps in a promitochondrial stage. Mitochondria with different forms of cristae may be noted. The outer cell wall appears as a small line with a density greater than normal. The fluffy particles coating the cell are pigmentation granules.

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* Abbreviations used for figures. Cw Cell wall, IS intermediate space, C Cytoplasm, N Nucleus, Nm Nuclear membrane, M Mitochondria, ER Endoplasmic reticulum, L Lipid, I invagination of the cytoplasm membrane, P Pores of the Nucleus, Cm Cytoplasm membrane.

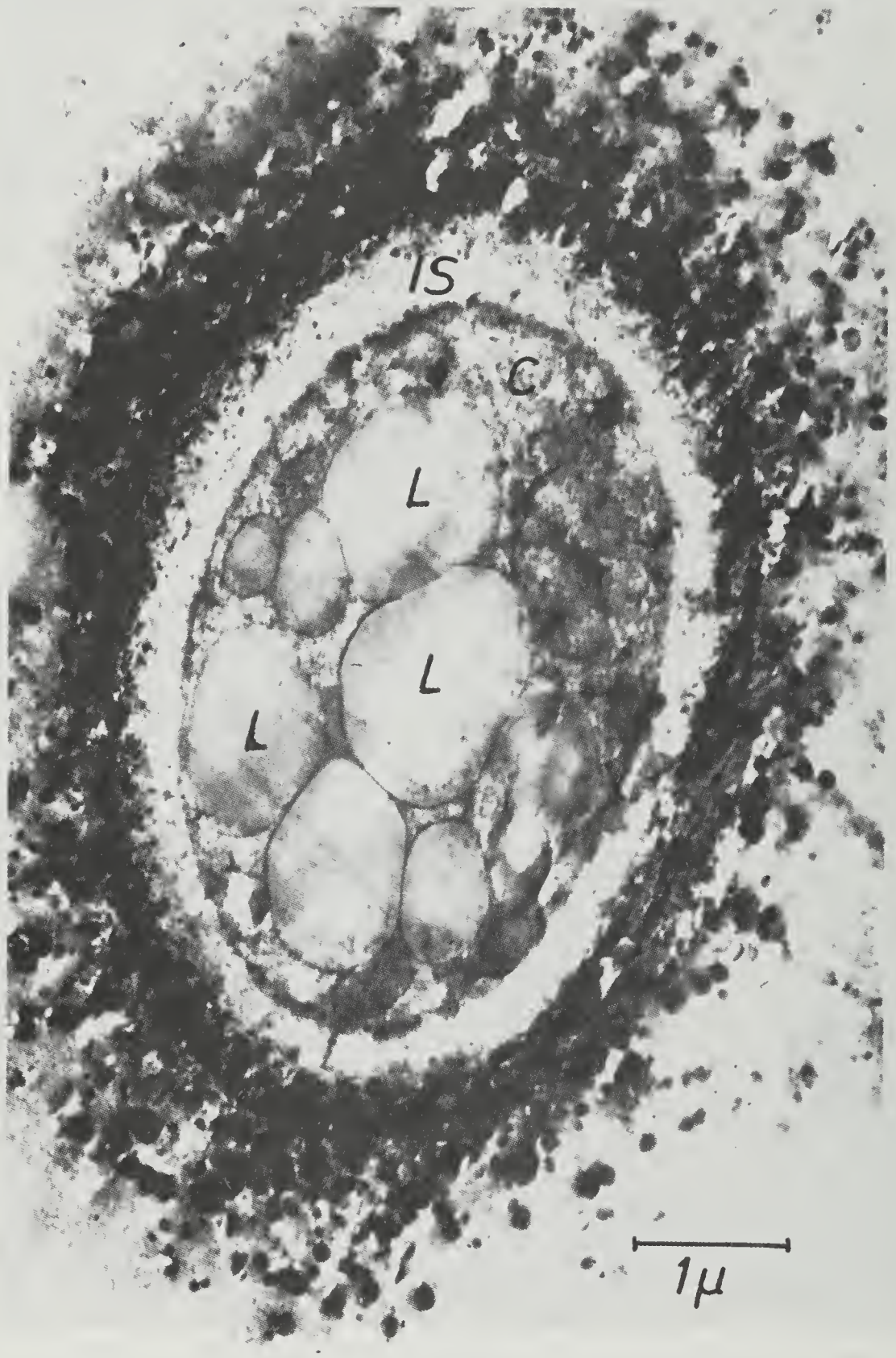

Fig. 3. Aureobasidium pullulans grown under aeration. The cell, surrounded by pullulan shows the cytoplasm filled with lipid bodies. The portion of the cell where the formation of pullulan was observed to originate was the IS as reported by Durrell (6). In the thin sections, black points of pullulan were found only in the outer portion, whereas the inner portion of the intermediate space seemed unchanged. Pigment initiation also seemed to occur in the IS.

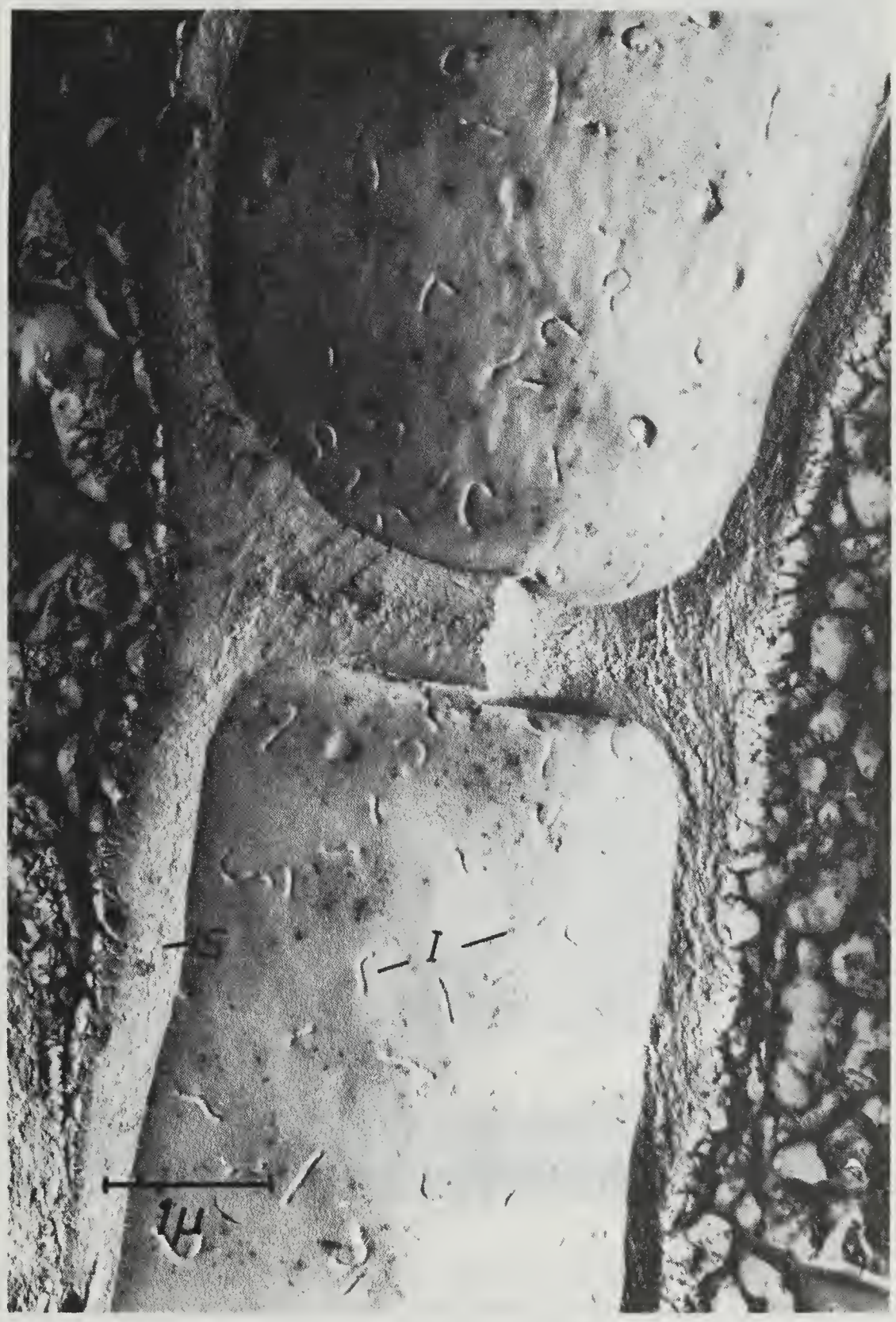

Fig. 4. The surface of the cytoplasm membrane. In the freeze-etched cell peculiar formed invaginations are visible which are not present within aerobically grown cells.

Fig. 5. A double cell in the early stage of aeration following anoxic cultivation. Lipid droplets are accumulating and the blastospore contains a great number of hypertrophic mitochondria. The inner mitochondrial space of the cristae contains only small lines and in some units are only found diffused zones, the inner zone seems lysed. This is observed to be the first stage of conversion to lipid bodies. The final stage-lipid bodies are also present.

present investigations revealed an increase in the radioresistance of A. pullulans in the logarithmic growth phase at constant pH and high aeration.

Swelling effects of mitochondria were described as occurring in many tissues, as heart, liver and others (7). David (4) gave a very complete picture of this effect. Hirano and Lindgren (8) noted the disappearance of mitochondria at the transition of aerobic to an anaerobic way of life, whereby the endoplasmatic structures increased. With longer aeration of A. pullulans mitochondria decreased in number proportionately with the increase of lipid in the cytoplasm. Though Duncan and Hild (5) discussed the question of whether mitochondria are able to change directly into lipid bodies, our experiments seem to present this as a definite possibility. That is, with the progress of the culture all mitochondria seemed to have changed to lipid bodies.

ACKNOWLEDGEMENT

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PIGEON HOMING: EFFECTS OF X-RAY RADIATION TO THE HEAD AND FOREBRAIN

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ABSTRACT

In an attempt to determine what role the forebrain of a pigeon has in homing behavior, portions of the forebrain were damaged by X-ray irradiation. At first the effect of 600 R of X-rays to entire heads of racing pigeon was studied. These birds did home in 80 km test flights as well as the controls and continued to do so for three summers following the irradiation for a total of 1780 km. A group of pigeons were then treated with 1500 R of X-rays to the whole head and these birds also homed for a total of 1725 km as well as the controls for several years. However, some birds that received 600 R and a year later 1500 R to the head homed the first and second summers, but premature senility appeared by the third year following radiation. These birds that received whole head irradiation of a total of 2100 R were test flown 1440 km. With the use of appropriate lead hoods, 10,000 R were administered to delimited 2, 10 or 15 mm diameter regions of the forebrain. No influence on homing behavior compared to controls could be detected in flights from 19 to 164 km. These birds flew 1474 to 2116 km over a 2-year period. Radiation induced lesions and damaged to olfactory nerves were detected upon autopsy of irradiated birds.

INTRODUCTION

Considerable attention has been given to the homing be-

havior of birds (Matthews, 1951; Hitchcock, 1952, Alexander and Keeton, 1972) and indications exist that besides visual cues, magnetic fields (Merkel and Wiltschko, 1965; Southern, 1972) may play a role in this activity. Papi et al. (1973) have proposed that olfaction plays an important role in the homing mechanism of pigeons. However, Keeton and Brown (1976) reported that a strong odorous substance (α-pinene) failed to cause a decrement in homing performance. The homing behavior of a pigeon is complex and the birds probably use whatever cues they can in homing. In an attempt to evaluate the role which the forebrain may play in homing, X-ray irradiation was used to injure this region of the central nervous system. The effect of X-ray radiation to the entire head was first determined. Then the forebrain alone was exposed by using appropriate lead hoods. A practical reason for testing the forebrain was that a small portion could be damaged without blinding the birds or rendering them incapable of flight.

METHODS

Prior to experimentation on the forebrain, the effect of radiation to the entire head with respect to homing was determined. One to 2 year old racing pigeons were intensively trained to home over a period of two to three months by releasing 16 to 80 km west of the campus loft. Six of these pigeons were then irradiated with 600 R of X-rays to the entire head. The X-rays were produced by a General Electric Maximar III at 225 KV, 15 amp, 32 cm., 245 R/min no filters. The pigeons were wrapped in a woolen sleeve to prevent wing beating and movement, and placed in a paper-padded wooden box lined with lead. The box had a small hole so only the head could protrude. A plastic ring was placed around the neck to prevent the bird from withdrawing from the X-ray beam. (Shown in Figure 1).

Since DeKalb, Illinois, is 97 km west of Chicago, releases of birds were either NW, W, or SW of the loft to prevent the birds from flying over a congested metropolitan district. They were released singly and the next bird was released only when the first one was out of sight. Distances ranged from 19 to 164 km. The direction of vanishing and time of arrival were recorded. If rain was predicted or the temperature was below 4°C, the birds were not released for testing. The homing tests were done once or twice a week from mid-April to early November for three years. On non-test days, the birds were exercised around the loft building. In individual experiments, equal numbers of control birds were employed. These were of the same age and sex as those exposed to radiation.

The following summer, eight pigeons were exposed to 1500 R of X-rays to the head. Six of these birds had never been irradiated, but the other two had been exposed to 600 R. These birds were observed and flown for three years.

In the forebrain experiments, a lead hood (Figure 2) was placed over the head of the bird while its body was still enclosed in the lead box. The hood was positioned so that the hole (either 2, 10 or 15 mm diameter) would permit the X-rays to enter the head only in the region of the forebrain. Precaution was taken not to injure the eyes and optic nerves. Five birds received a 10,000 R-exposure of X-rays to a 2 mm diameter region in the middle of the forebrain, while another five birds were exposed to 10,000 R to a 10 mm region of the forebrain. These two groups along with appropriate controls were flown an average total of 1474 km and were observed over a 2 year period.

An additional 19 pigeons received 10,000 R of X-rays to a 15 mm diameter region of the forebrain and were flown 33 times for an average total of 2116 km. Twenty different flight release sites were used. Three of these were for training and were used prior to head irradiation. The treated birds were thus released from 17 sites for the first time.

Pigeons receiving irradiation to the forebrain were autopsied and damage was noted.

RESULTS

The six pigeons whose entire heads were irradiated with 600 R of 225 KV X-rays homed as efficiently as the six controls when released an hour after irradiation at a distance of 32 km west of the loft. These birds had good reflexes as demonstrated by avoiding reactions to captives in the loft. Two days later when the same birds were released 48 km to the west, they disappeared from view at single releases in the correct direction and homed as quickly as the controls. These birds continued to act normally, leaving the loft for their daily exercises and were flown at release points 24 to 80 km west of the loft. By the following summer the irradiated birds and the controls had logged an average of 480 km and none had been lost. They mated, their general behavior was normal; however, they could easily be distinguished from the rest of the flock by white head feathers induced by the radiation (Figure 3). Eventually these birds homed for an average total of 1780 km, showing no significant differences from the controls. The summary of their homing data is presented in Table 1.

Table 1. Summary of the Results of Homing Tests

Radiation exposure	Test period years	Total cummulative distance flown, km.	Number of releases	Number of birds	Number lost or (failed to return)	Mean deviation in disappearance from view in degrees	Mean speed (if the bird arrived the same day of release) km/hr.
Series No. 1							
600R to entire head	3	1780	31	6	1	23°	29.4
Controls	3	1780	31	6	1	27°	28.7
Series No. 2							
1500R to entire head	3	1725	30	8	1	21°	26.7
Controls	3	1725	30	8	1	27°	25.5
600R + 1500R to entire head	2	1440	26	2	0	41°	15.2
Series No. 3							
10,000 to 2 mm of forebrain	2	1474	27	5	0	22°	27.6
Control	2	1474	27	5	1	19°	25.5
Series No. 4							
10,000R to 10 mm of the forebrain	2	1474	27	5	1	18°	28.1
Control	2	1474	27	5	0	24°	26.9
Series No. 5							
10,000 to 15 mm of the forebrain	1	2116	38	19	2	30°	25.1
Control	1	2116	38	19	2	27°	24.5

Pigeons which received 1500 R and those that were irradiated for a total of 2100 R (1500 R + 600 R) to the entire head were released at points 48 to 80 km west of the loft over a period of 3 years. No differences in homing ability between controls and these irradiated birds were noted for three years in those birds receiving 1500 R of X-rays. Further, 1500 R to the entire head failed to interfere with mating behavior and rearing of the young. A month after exposure, loss of and changes in the colors of head feathers were noticed, and two months later, light spots and pale discolorations were observed in the irises (Figure 4). The discolorations of the irises and the induced white head feathers persisted for the entire life of the bird.

Birds receiving a total of 2100 R (Figure 5) homed as well as controls during the first summer after irradiation. However, by the next year they began to home slower (Table 1) and showed behavioral signs of premature aging. Three years after the first head irradiation, one of the birds had become potently senile and this group was then excused from the test flights. By this time, birds receiving 2100 R had homed an average total of 1440 km.

Birds which had received 10,000 R to portions of the forebrain through 2, 10 or 15 mm openings in the lead hood were not at all affected in their ability to home (Table 1). Although these birds had different colored leg band markers, they could easily be distinguished from the rest of the flock by the whitish feathers in the exposed regions of the head. Autopsies of these birds did indicate radiation damage to anterior portions of the forebrain and to olfactory nerves.

DISCUSSION

The central nervous system of adult animals is generally regarded as being highly resistant to ionizing radiation. Whether one accepts 920 R as the LD_{50-30} day for pigeons (whole body radiation) as determined by Skala and Hill (1952) or 2050 R as the LD_{50-30} day as reported by Stearner and Tyler (1962), the evidence obtained in the present studies of whole head irradiation indicates that the homing ability is fairly resistant to X-ray irradiation. Conflicting views are presented in the literature with respect to the sensitivity of the nervous system to radiation. Lebedinsky et al (1958) state that low doses of radiation, 10 R or less can affect biolectrical activity and reflex time. However, Stahl (1960) reported that alterations in these indicators of damage are resistant to moderate amounts of radiation. Krabbenhoft (1955) found that supralethal doses above 1000 R must be given to produce detectable changes in brain structure, while Caster et al (1958) claim that although the central nervous system is resistant to radiation, small populations of sensitive cells can be detected. In a study reported by Kramer

and Michaelson (1972) in which 1000 R was given to the heads of beagles, this exposure failed to result in abnormal behavior in these dogs 30 months later; however, diffuse neuronal alternations and changes in the electroencephalogram were detected.

Pigeons which received a total of 2100 R, whole head irradiation, did not home as well as the controls during the second year and were also easier to catch in the loft. However, during the first year, no differences were evident in the behavior of these birds with respect to the controls both in avoiding capture and in homing speed. The latent senility was not detected in those birds that received 600 or 1500 R whole-head irradiation after 3 years of flying.

In mammals, whole body doses of 10,000 R or higher usually produce death in a day or two after exposure as a result of damage to the nervous system. This is usually termed central nervous system, (Casarett, 1968). Although portions of the forebrain were severely damaged by 10,000 R of X-rays, the birds in the present experiment did home and were behaviorly unaffected. In positioning the hood with 15 mm diameter opening to irradiate the forebrain and in avoiding the optic region to prevent blindness, the olfactory nerves were exposed to radiation. These birds homed and reacted as well as controls. This evidence supports the conclusions of Keeton and Brown (1976) that olfactory cues do not play an important role in pigeon navigation.

The forebrain was selected as part of the nervous system that could be damaged and partially destroyed but which would not interfere with vision and the ability to fly. Apparently, this region does not specifically house the ability to detect or interpret magnetic cues. Subjecting the anterior region of the forebrain to 10,000 R failed to affect the homing behavior even when the birds were released from distant sites for the first time. The homing behavior thus appears to be property of a larger portion of the brain or some other specific region. Several components of this behavior probably exist in the trained bird and as in general learning, it is likely that the entire brain may be involved, with cues arising from anatomical sensors even outside the central nervous system.

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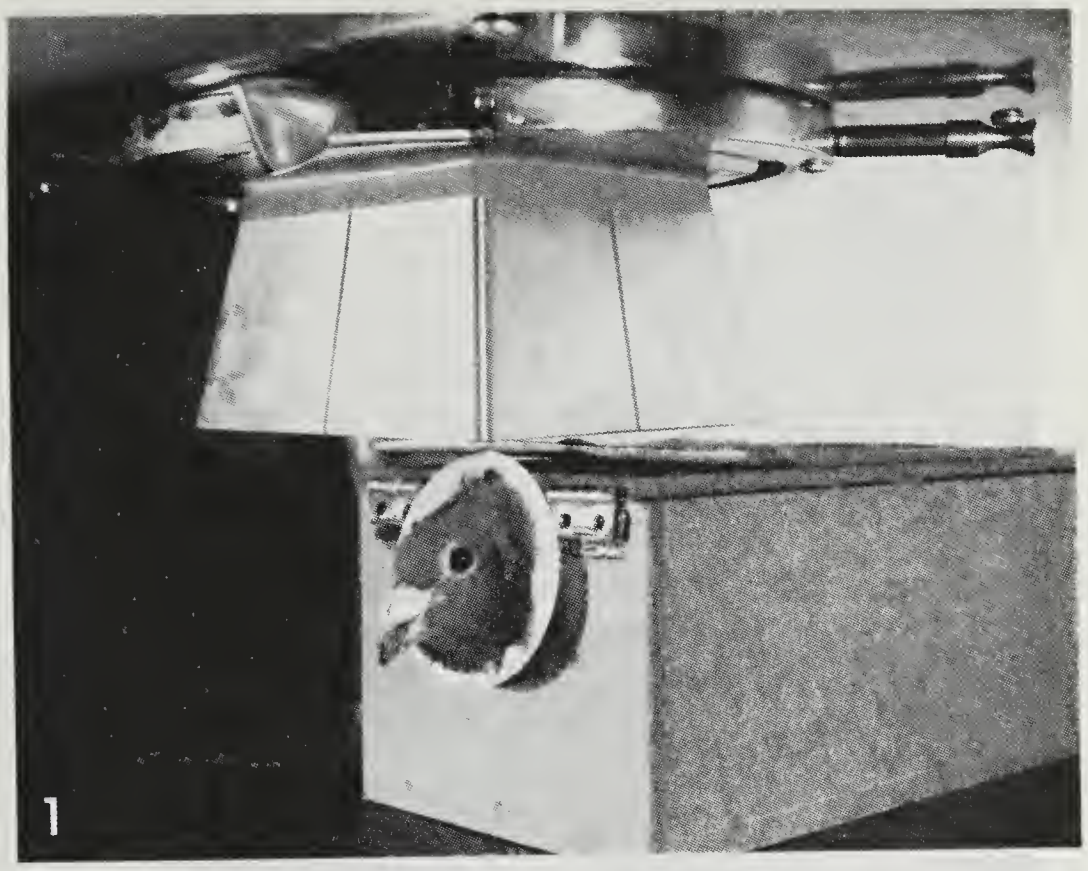
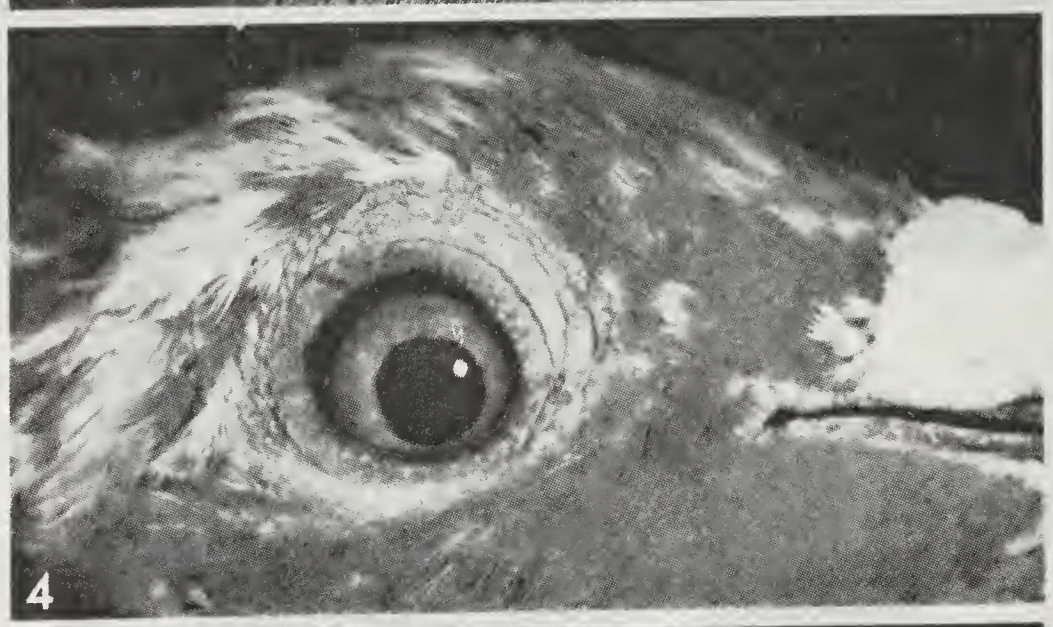


Plate 1

Figure 1. Pigeon in position to receive whole head X-ray radiation.

Figure 2. Hoods with 2, 10 and 15 mm diameter openings used to irradiate portions of the forebrain.



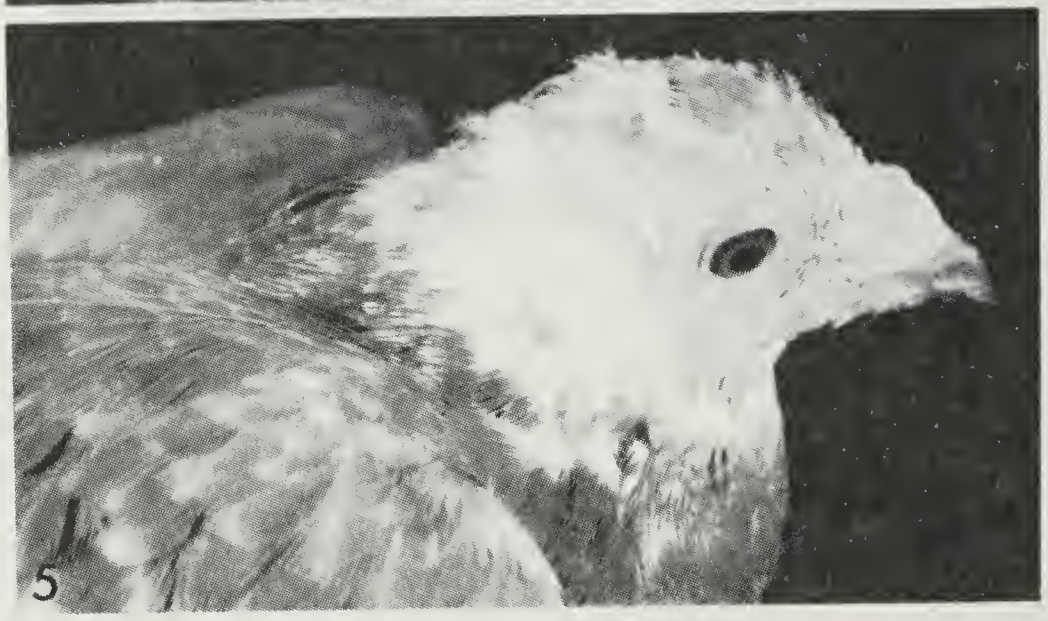


Plate 2

Figure 3. Head of pigeon three months after receiving 600 R of X-rays. Some of the feathers grew back white and gray.

Figure 4. Discoloration of the iris and white feathers induced by 1500 R of X-rays.

Figure 5. Head of pigeon six months after receiving a total of 2100 R.

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MILO IN THE DIET OF WHITE-TAILED DEER FROM SOUTHERN ILLINOIS

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ABSTRACT

In a study of fall food habits of white-tailed deer on Crab Orchard National Wildlife Refuge, milo was the second most important food after honeysuckle, occurring in over two-thirds of all rumens sampled and making up one-third of the volume. As milo consumption increased, consumption of other foods decreased. Also, fewer different items were found when milo consumption was relatively high. Milo consumption declined over the one-month interval between collection periods. Several possible reasons are cited for the decline. Although milo was apparently more available than corn, its importance was believed to be primarily a result of preference, rather than mere availability.

INTRODUCTION

Food habits of white-tailed deer (Odocoileus virginianus) have been well documented; however, there is a lack of information on the use of milo (Sorghum bicolor) as a food item. The management program on Crab Orchard National Wildlife Refuge (CONWR) involves leaving about one-third of the milo and corn (Zea mays) crops unharvested as winter food for Canada geese (Branta canadensis) (unpubl. data, CONWR). In 1974 this amounted to around 120 ha (18,000 bushels) of milo and 216 ha (23,400 bushels) of corn. These grain crops and any waste residues after harvest are also available to a large refuge deer herd in the fall and early winter. This paper represents a portion of a study to determine fall food habits of the CONWR deer.

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MATERIALS AND METHODS

The study area, a portion of CONWR, was opened to a special hunt coinciding with the 1974 split deer season in Illinois. A 4,280-ha area south of Crab Orchard Lake was hunted during 15-17 November and a 2,040-ha area north of the Lake was hunted during 13-15 December.

Rumen samples provided by successful hunters were frozen until analyzed. After thawing, each sample was subdivided by washing it through a series of four screens with 2-, 4-, 8- and 16-per inch meshes to permit the analysis of particles of similar size. The point technique (Chamrad and Box 1964) was used in the analysis of all samples. Plant identification keys and reference collections aided in the identification of plant parts. Each food item was recorded by percent frequency (i.e., whether or not it occurred in a sample) and percent volume (as determined by the point technique). Importance values were determined by multiplying percent frequency by percent volume.

The sex, age, field dressed body weight and antler beam diameter (where appropriate) were recorded for each harvested deer and the location of each kill was plotted on aerial photographs of the Refuge. A weekly 17-mile automobile census was used to determine relative population levels on the study area [Cooperative Wildlife Research Laboratory (CWRL) records]. Data were averaged for a 6-month period preceding each hunt. Agricultural practices on the study area were determined from land use records at CONWR and through a survey of aerial photographs.

RESULTS AND DISCUSSION

Contents of 173 rumen samples were analyzed to determine diet. To evaluate diets of deer of different sex and age, data for 112 (14 in each of the 0.5, 1.5, 2.5, and 3.5+ year sex-age classes) deer harvested on the south area were compared with data from 56 (7 per age class) harvested from the north side.

Deer on CONWR had a relatively simple diet during the fall (Table 1). Forty-five plant items were identified in addition to eight categories of unknowns. The top five foods accounted for over 85 percent of the mean volume of all samples. Honeysuckle (Lonicera japonica) and milo were the two primary foods, rating far above all others in importance values (Table 1).

TABLE 1. Percent volume, percent frequency, and importance values for the foods occurring in 173 rumens taken from CONWR deer during November and December, 1974.

	Plant	Part(s) Eaten	$\bar{X}$ % Vol.	$\bar{X}$ % Freq.	Importance Value
1)	*Lonicera japonica*	leaves, stems	30.39	98.3	2,987.3
2)	*Sorghum bicolor*	seed heads	33.14	68.2	2,260.1
3)	Gramineae and Cyperaceae	blades	4.74	82.1	389.2
4)	*Zea mays*	grain, cobs, silk, stalks	11.08	34.1	377.8
5)	*Plantago* spp.	leaves	1.31	26.0	34.1
6)	*Gleditsia triacanthos*	seed pods	1.19	19.7	23.4
7)	*Rhus glabra*	fruiting heads	0.70	25.4	17.8
8)	*Prunus serotina*	leaves	0.82	19.7	16.2
9)	*Diospyros virginiana*	fruit	0.60	20.8	12.5
10)	*Rosa* spp.	leaves, fruit	0.61	20.2	12.3
11)	*Pinus* spp.	needles	0.83	13.9	11.5
12)	*Smilax* spp.	leaves	0.62	17.3	10.7
13)	*Rubus* spp.	leaves	0.20	10.4	2.1
14)	*Acer* spp.	leaves	0.35	10.4	3.6
15)	*Trifolium* spp.	leaves	0.25	9.8	2.5
16)	*Symphoricarpos orbiculatus*	fruit	0.19	7.5	1.4
17)	*Lespedeza stipulacea*	leaves	0.25	5.2	1.4
18)	*Quercus* spp.	acorns	0.39	2.9	1.1
19)	*Vitis cinerea*	fruit, leaves	0.46	4.6	0.7
20)	*Polystichum acrosticoides*	fronds	0.13	3.5	0.5
21)	*Glycine max*	seed pods	0.13	1.2	0.2
22)	*Daucus carota*	leaves	tr.	4.6	--
23)	*Allium vineale*	aerial parts	tr.	2.9	--
24)	*Ulmus* spp.	leaves	tr.	1.1	--
25)	*Juniperus virginiana*	needles	tr.	2.3	--
26)	*Lespedeza cuneata*	leaves	tr.	2.9	--
27)	*Cornus florida*	leaves, seeds	tr.	1.7	--
28)	*Antennaria plantaginifolia*	leaves	tr.	0.6	--
29)	*Melilotus* sp.	leaves	tr.	2.3	--

TABLE 1. Continued.

	Plant	Part(s) Eaten	$\bar{X}$ % Vol.	$\bar{X}$ % Freq.	Importance Value
30)	*Ambrosia artemisiifolia*	leaves	tr.	1.2	--
31)	*Malus pumila*	leaves	tr.	0.6	--
32)	*Glecoma hederacea*	leaves	tr.	0.6	--
33)	*Ipomoea* sp.	flower	tr.	0.6	--
34)	*Passiflora incarnata*	fruit, seed	tr.	1.7	--
35)	*Polygonum pennsylvanicum*	seed	tr.	1.2	--
36)	*Cuscuta* sp.	leaves	tr.	0.6	--
37)	*Oxalis* sp.	leaves	tr.	0.6	--
38)	*Euphorbia serpens*	leaves	tr.	0.6	--
39)	*Parthenocissus quinquefolia*	leaves	tr.	0.6	--
40)	*Quercus* spp.	leaves	tr.	0.6	--
41)	*Ulmus americana*	leaves	tr.	0.6	--
42)	*Liriodendron tulipifera*	leaves	tr.	0.6	--
43)	*Fraxinus* sp.	seed	tr.	0.6	--
44)	*Achillea millefolium*	leaves	tr.	0.6	--
	UNKNOWNS:				
1)	Woody spp.	leaves	7.35	83.8	615.9
2)	Woody spp.	stems	0.84	40.5	34.0
3)	Herbaceous spp.	leaves	1.49	60.7	90.4
4)	Herbaceous spp.	stems	1.11	38.7	43.0
5)	--	fragments	0.14	8.1	1.1
6)	--	seeds	tr.	0.6	--
7)	Woody spp.	fruit (nuts)	tr.	0.6	--
8)	Herbaceous spp.	fruit	tr.	1.2	--

Various authors have noted the importance of honeysuckle in the diet of deer (Thorsland 1966, Nixon et al. 1970, Segelquist et al. 1971, Sheldon and Causey 1974), and have reported that deer use most of the other items found in CONWR deer rumens; however, little information has been published on milo in the diet of deer.

TABLE 2. Significant correlations* between percent milo consumption (by volume) and percent consumption of other foods, based on 173 rumen samples from deer harvested from CONWR in 1974.

	Correlation Coefficient
% milo with % honeysuckle	- 0.5996
% milo with % corn	- 0.3589
% milo with % grasses and sedges	- 0.2265
% milo with % woody leaves	- 0.3002
% milo with number of different food items	- 0.3391

*α = 0.01.

Milo has only recently come into widespread use as a grain crop in southern Illinois (Martin and Leonard 1967). According to Crampton and Harris (1969) it is a nutritionally well-balanced food, averaging 12.4 percent protein, 4,389 kcal/kg energy, and 0.33 percent phosphorus. These levels are considered moderate to high in these required nutrients for deer (Urness 1973). In the present study negative correlations (not all significant) were noted between percent milo consumption by volume and percent consumption of the other foods considered, and variety of items consumed per sample (Table 2). When consumption of milo increased, consumption of other foods decreased, suggesting that deer could get most of their nutrients from milo. Comparing dressed body weights and antler characteristics of CONWR deer (Table 3) with those for deer from other parts of southern Illinois (Richie 1970), it appears that milo in conjunction with the other foods consumed is supportive of good herd condition. Richie (1970) noted that both male and female fawns and yearling males averaged slightly heavier ($\bar{X}_{mf}$ = 61 lbs, $\bar{X}_{ff}$ = 53 lbs, $\bar{X}_{ym}$ = 112 lbs) than those in the present study. However, weights of other sex and age classes were virtually identical to those in the present study.

TABLE 3. Mean field dressed body weights and antler beam diameters of deer harvested from CONWR in 1974.

	Age (Years)	Mean Field Dressed Body Weight (lbs)	Mean Antler Beam Diameter (mm)
Males	0.5	54.2	--
	1.5	101.3	17.5
	2.5	138.0	27.0
	3.5+	163.1	33.3
Females	0.5	48.9	
	1.5	83.9	
	2.5	93.9	
	3.5+	97.6	

TABLE 4. Percent volume, percent frequency, and importance values for the four principal foods in 114 and 59 deer rumen samples collected during the November (south) and December (north) CONWR hunts, respectively, in 1974.

	November Hunt			December Hunt		
Plant	$\bar{X}$ % Vol.	$\bar{X}$ % Freq.	Imp. Value	$\bar{X}$ % Vol.	$\bar{X}$ % Freq.	Imp. Value
Sorghum bicolor	43.47	85.1	3,699.3	13.2	35.6	469.9
Lonicera japonica	24.25	96.5	2,340.1	42.2	100.0	4,220.0
Gramineae and Cyperaceae	5.15	83.3	429.0	4.0	79.7	318.8
Zea mays	4.47	14.9	66.6	23.9	71.2	1,701.7

A decline in milo consumption was noted between the first (south) and second (north) hunts, coinciding with an increase in honeysuckle and corn consumption (Table 4). Milo acreage on the south area made up 6.5 percent of the land use, while accounting for only 3.5 percent of the land use on the north side (Table 5). This partially explained the substantial drop in milo consumption between the two areas. The dramatic decrease in milo consumption and increase in corn consumption between the November and December hunts suggested that deer tended to turn to corn only after the supply of milo had diminished.

The rapid deterioration of milo when exposed to weather (DeVos and Mosby 1971) may partially account for its decline in consumption over the one-month interval between the hunts. Other possible explanations for the decline include a shift in preference from milo to corn, greater availability of corn or other more preferred foods on the north area, or greater competition for corn on the south where the average number of deer seen per mile was substantially higher than on the north area. Less milo may have been available on the north area as a result of the time differential and due to the geese, which tend to feed first in the center of open fields and move toward the edges (Bell and Klimstra 1970) where they compete more directly with the deer for food. While it is probable that milo grown near woody cover received heavier utilization by deer there was no evidence that a greater proportion of milo than corn was situated near woods on either of the study areas.

TABLE 5. Deer data, acreage, and land uses along the study areas on CONWR.

	$\bar{X}$ deer seen per mile*	$\bar{X}$ deer killed per mile	Total area (ha)	Percentage in each land use type				
				Pasture	Milo	Corn	Hay & Clover	Woody & other cover
South area	20.3	90.1	504	7.6	6.5	8.2	6.7	71.0
North area	6.9	34.8	291	10.5	3.5	14.6	10.3	61.1
Total	14.0	64.1	795	8.6	5.4	10.4	7.9	67.7

*Based on CWRL census data collected prior to the harvest.

Honeysuckle and corn consumption showed weak negative correlations with mean number of deer seen per mile ($r = -0.194$, $\alpha = 0.05$, and $r = -0.255$, $\alpha = 0.01$, respectively), whereas milo consumption and mean number of deer seen per mile were positively correlated (not statistically significant) (Table 5). Thus, as numbers of deer increased, corn and honeysuckle consumption decreased, whereas milo consumption was apparently not affected by deer numbers. It seemed likely that deer were attracted to the milo, as the percentage of land in milo (5.4 percent) was about half that in corn (10.4 percent) yet the consumption by percent volume of milo was almost three times that of corn (Table 1). By percent frequency it was about twice that of corn. More deer were observed in areas where milo was abundant. Milo was apparently more easily obtainable than corn, as there was little difference in the consumption of milo among the different age classes except for fawns, which generally showed the lowest consumption of corn and higher consumption of milo (Table 6).

Evaluation of pre- and post-hunt censuses indicated a pre-hunt density of one deer per 2.3 ha on the study area (CWRL records). This is an extremely high density, as one deer per 32 acres (12.8 ha) has been reported as an average density (Hosley 1956). Apparently the abundance and availability of agricultural crops serve to buffer the impact of deer on native vegetation and effectively raise the carrying capacity of the area.

TABLE 6. Percent volume of milo and corn consumed by animals representing selected age classes of deer harvested from CONWR in 1974.

	MALES Age (Years)				FEMALES Age (Years)			
	0.5	1.5	2.5	3.5+	0.5	1.5	2.5	3.5+
November								
Milo	55.2	47.4	48.8	38.1	43.1	35.4	41.9	38.7
Corn	--	1.5	16.1	0.9	2.9	4.4	6.1	5.2
December								
Milo	1.4	7.9	10.5	6.4	22.7	11.4	30.4	11.3
Corn	13.1	25.6	59.1	43.5	9.4	14.7	9.7	9.8

While corn and milo are heavily used by deer on CONWR, it is not suggested that the level of utilization be considered an index of deer density, as variation in crop yields from one year to the next or planting patterns might affect the use deer make of grain. The degree of utilization of these grain crops however, should be of substantial concern in any management program for CONWR deer because it is extremely unlikely that the native plants could support such a high deer density.

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ACID PHOSPHATASE ISOZYME PROFILES IN THE LIFE CYCLE OF THE NEMATODE PANAGRELLUS SILUSIAE

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ABSTRACT

The lysosomal enzyme acid phosphatase was studied throughout the life cycle of the free-living nematode, Panagrellus silusiae. Ten different isoenzymes of acid phosphatase were separated by polyacrylamide gel disc electrophoresis. As the nematode ages, there is a general decrease in the relative activity of acid phosphatase itself, while there is a concurrent increase in the number of isozymes present. Through the use of Triton X-100, 97% of the enzyme was found to be soluble (unbound). From a light microscopic study, acid phosphatase was found to be present in large quantities in the digestive, excretory, and reproductive systems.

INTRODUCTION

Since the late 1920's, many theories have been suggested as possible explanations for aging, but little agreement seems to exist regarding its true nature.

Strehler (1962) proposed that aging must be (1) universal, occurring in all old animals of a species, (2) time dependent, progressing gradually in an individual and the population, (3) intrinsic, due to the action of time on the biological system, and (4) deleterious, unfavorably effecting the individual's survival capacity.

Based on the concept that aging is a universal phenomenon among metazoans, Gershon (1970) considered the nematode to be suitable for aging studies, because (1) it is possible to obtain age-synchronized populations and to establish survival curves, (2) the nematode's growth and life-span are not altered by up to 90% inhibition of DNA synthesis, and (3) it yields large populations under easily controlled conditions, thus making it fit for biochemical investigations.

Since nematodes are eutelic organisms, cell division and turnover are negligible and most cells are already differentiated after hatching (Hyman, 1951), making any deteriorative processes leading to senescence

more easily observable. The nematode chosen for this study was the free-living form, Panagrellus silusiae.

The lysosome has been implicated as part of the terminal lytic aging process (Brock and Strehler, 1968; Herold and Meadow, 1970; Hochschild, 1971). Since the lysosomal enzyme chosen for this study, acid phosphatase, is considered to be a lysosomal marker, it follows that it too may be linked to the aging process. Therefore, the purpose of this study was to investigate the hydrolytic enzyme acid phosphatase and its role in the aging process, to add to the present understanding of the causes and mechanisms of the biological phenomenon of aging.

MATERIALS AND METHODS

Stock cultures of P. silusiae were maintained at 23-25°C. The growth medium was Gerber Mixed Cereal mixed with distilled water in a weight to volume ratio of 1:5. Each culture was maintained for 14 days. A dilute antibiotic solution of 0.6 μg penicillin-G and 10 μg streptomycin/ml was added to the nematodes during subculturing to avoid contaminating the fresh cultures.

P. silusiae is an ovoviviparous animal with five larval stages. The first larval stage (L_1) is intrauterine, but the remaining stages (L_2, L_3, L_4 and L_5) are free-living. The different stages were identified by the average lengths of worms, as recorded by Gysels and van der Haegen (1962).

After sample collection, the nematodes were separated by age using the glass microbead technique outlined by Samoiloff and Pasternak (1969). Since this procedure only separated the youngest free-swimming larval stage, it was necessary to obtain as many L_2 worms as possible. Therefore, 7-day-old cultures were placed in the dark for 16 hrs prior to sample collection, to induce the nematodes to reproduce, since P. silusiae tends to copulate more often while in darkness, thus producing more L_2 larvae.

When later stages were to be studied, the L_2 were allowed to molt at 23-25°C to a more advanced stage of the life cycle. Following the work of Chow and Pasternak (1969), the L_2 larvae were added to petri dishes containing 10 ml of clear 1% barley solution, so that the ensuing growth to maturation would be highly synchronous. In the barley solution, L_3 larvae were obtained in 24 hrs, L_4 in 48 hrs and adults (L_5) in 72 hrs.

The nematodes were also kept in the 1% barley solution until they were 10, 15, 20 and 25 days old, in order to study aging of adult worms. This part of the study was conducted at 5°C, which allowed the adults to age, but not to reproduce, so that new L_2 larvae would not be born into the age-synchronized cultures. Every 24 hrs, 1 ml of fresh barley solution was added to the petri dishes in each experiment, to offer fresh nutrients.

The nematodes to be studied were concentrated by centrifugation and ground on ice to minimize denaturation. In each experiment, the protein content of the samples was determined using the method of Lowry et al. (1951).

The electrophoretic medium chosen was polyacrylamide gel. The Research Disc Electrophoresis Standard Reagent Kit from Canalco (Rockville, Md.) was used. The procedure outlined in the Canalco instructions was followed, with the following exceptions. The bridge buffer used was an 0.01 M histidine-NaOH buffer of ph 7.5, which was suggested by Robinson (1972). The gels were 10% acrylamide and were run at 6°C at 4 ma/tube. The sites of acid phosphatase on the gels were determined using the reaction method of Barka (1961).

In order to quantify the electrophoretic results obtained, densitometric tracings of the gels were made immediately after the end of incubation at 515 nm. The relative activity of each peak was calculated by dividing the peak height by the µgs of protein applied to the gel (Bolla et al., 1974).

Triton X-100, a detergent which disrupts lysosomal membranes, was utilized to determine the amount of membrane bound and unbound acid phosphatase in the different nematode stages. Modifying the assay procedure of Meany et al. (1967), Triton X-100 was added to a mixture of the stages of P. silusiae using six different methods of introduction and the following concentrations: 0.1%, 0.5%, 1.0%, 2.5%, 5.0%, 10%, 25%, 50%, and 100%. The six methods of adding the detergent are as follows: (1) immediately before the nematodes were ground for electrophoresis, (2) 10 min before grinding the nematodes, (3) 10 min at 37°C before grinding the tissue for electrophoretic experimentation, (4) immediately after grinding the nematodes, (5) to pre-ground tissue 10 min before experimentation, and (6) to pre-ground nematodes 10 min at 37°C before running electrophoresis. Each concentration of Triton X-100 was added to the worms in all six methods used. Each result was compared with the appropriate control of distilled water, and equal portions of nematodes and detergent were used in each case.

To ascertain the quantity of acid phosphatase liberated in each trial, the Sigma total acid phosphatase test (Sigma Technical Bulletin #104) was run on a sample from each test at 410 nm. Percent transmittance was converted to Sigma units/ml of acid phosphatase, using a standard curve based on p-nitrophenol.

To determine which structures within P. silusiae contain acid phosphatase, a light microscopic study was done on each larval stage. The tissue was fixed in 1:10 commercial formalin for 1 hr, and dehydrated in an ascending series of ethanol solutions following the procedure of Jensen (1962). The worms were infiltrated with paraffin, positioned in paraffin blocks and sectioned at 10 µ. The sectioned tissue was affixed to glass slides and stained using the acid phosphatase-lead sulfate procedure of Gomori's (1952) which was modified by Jensen (1956). The control for this study was heat killed tissue (i.e., boiled in distilled water for 5 min) carried through the entire staining process.

RESULTS

This study showed that there is a relationship between acid phosphatase activity and age in P. silusiae. Ten separate and distinct

isoenzymes existed. The L_2 and L_3 stages each showed 4 isozyme bands on the gels. Five separate isozymes were present in the L_4, and 6 distinct bands were found on the gels of the L_5, 10-day, 15-day, and 20-day-old nematodes. The oldest nematodes studied (25 days old) showed 7 isozymes of acid phosphatase, which was the largest number present in any stage of the life cycle. Only 2 of the 10 isoenzymes separated were present in all 8 of the stages studied. The average electrophoretic mobility (E_f) values are listed in Table 1; a dash (-) indicates that the isozyme was not present at that particular stage. Isozyme 10 always travelled beyond the tracking dye, therefore resulting in an E_f value of greater than 1.0.

The isozymes of acid phosphatase stained in one of three ways on the gels. The bands appeared either red, faint red, or yellow in color. By conducting a Sigma total acid phosphatase test on each individual band, it was determined that each colored band was truly acid phosphatase.

TABLE 1: AVERAGE ELECTROPHORETIC MOBILITY (E_f) VALUES

stage \ band #	1	2	3	4	5	6	7	8	9	10
L_2	-	.118	-	.258	-	.352	-	-	-	1.143
L_3	-	.108	-	-	-	.353	-	-	.645	1.139
L_4	-	.118	-	-	-	.352	.516	-	.646	1.141
L_5	-	.127	-	-	.314	.350	.518	-	.640	1.147
10 day	.036	-	-	-	.317	.354	.514	-	.640	1.143
15 day	.034	-	.137	-	.309	.350	-	-	.646	1.140
20 day	.033	-	.139	-	.310	.352	-	-	.638	1.141
25 day	.035	-	.141	-	.317	.351	-	.396	.645	1.139

The relative activity of each of the separated isozymes of acid phosphatase was calculated directly from the densitometric tracings. The values obtained appear in Table 2; a dash (-) indicates that the isozyme was not present in that particular stage. By studying these values, it can be seen that some isozymes increase or decrease in relative acivity with an increase in the age of the nematode. However, as the nematode ages, there is a general decrease in the relative activity of the enzyme itself, while there is a concurrent increase in the number of isozymes present.

TABLE 2: RELATIVE ACTIVITY OF ACID PHOSPHATASE (peak height/μg protein applied to gel)

stage \ peak #	1	2	3	4	5	6	7	8	9	10
L_2	-	2.50	-	2.02	-	2.26	-	-	-	1.07
L_3	-	2.73	-	-	-	2.32	-	-	0.95	1.28
L_4	-	2.62	-	-	-	2.62	1.25	-	1.04	1.18
L_5	-	1.57	-	-	0.67	0.50	0.47	-	1.11	0.95
10 day	0.22	-	-	-	0.35	0.37	0.33	-	1.11	0.50
15 day	0.30	-	0.56	-	0.35	0.35	-	-	1.54	0.37
20 day	0.24	-	0.38	-	0.30	0.34	-	-	1.04	0.35
25 day	0.22	-	0.16	-	0.18	0.30	-	0.32	1.03	0.26

The results of the Triton X-100 study are listed in Table 3. Method I (added and ground immediately) liberated only 2% more acid phosphatase than that liberated by the distilled water control, while method II (added and ground after 10 min) showed no increase in the level of acid phosphatase obtained. Method III (added and ground after 10 min at 37°C) and method IV (added immediately to ground tissue) yielded a 3% increase in acid phosphatase activity. Method V (ground 10 min after it was added) showed no change in the enzyme level, and method VI (ground 10 min after it was added at 37°C) liberated only 1% more acid phosphatase than the control. Since Triton X-100 liberates membrane-bound enzymes, the results of these 6 trials indicate that only a negligible amount of acid phasphatase is bound to membranes within the cells.

TABLE 3: EFFECT OF CONCENTRATIONS OF TRITON X-100 ON ACID PHOSPHATASE ACTIVITIES USING P-NITROPHENOL AS A SUBSTRATE (values expressed in Sigma units/ml of acid phosphatase)

Method Conc. of Triton X-100	I	II	III	IV	V	VI
0.0%	0.40	0.34	0.39	0.54	0.45	0.51
0.1%	0.41	0.34	0.34	0.55	0.44	0.45
0.5%	0.42	0.32	0.38	0.57	0.39	0.44
1.0%	0.40	0.30	0.39	0.57	0.39	0.50
2.5%	0.35	0.27	0.41	0.52	0.40	0.50
5.0%	0.41	0.31	0.42	0.58	0.43	0.52
10%	0.35	0.29	0.40	0.49	0.44	0.48
25%	0.39	0.27	0.39	0.52	0.44	0.44
50%	0.40	0.31	0.34	0.50	0.40	0.47
100%	0.35	0.30	0.35	0.55	0.44	0.51

In order to determine what structures within P. silusiae contain acid phosphatase, the nematodes were specifically stained for the enzyme, and studied using light microscopy. The controls of heat killed tissue were run for each stage to prove that any staining was truly due to the presence of acid phosphatase and not to something in the staining process itself. In the experimental studies, any structure that appeared black in color contained acid phosphatase.

Only the digestive tract stained lightly in the L_2 stage. The L_3 stage stained lightly throughout the length of its body and the faint line of the intestine was again visible. This indicates that these two stages contain small amounts of the enzyme. In the L_4, a large amount of staining occurred. For the first time, the esophagus and intestine stained darkly, indicating large amounts of acid phosphatase were present. Also, the immature gonads which begin to develop in this stage, stained positively for the enzyme. A number of structures stained in the L_5 (adult) stage, including the entire gastrointestinal tract, the fully developed reproductive system, the excretory canals and eggs within the bodies of sexually mature L_5 females. L_1 worms waiting to emerge from the bodies of adult females also stained lightly, indicating the presence of a small amount of acid phosphatase.

DISCUSSION

These experiments would be relatively meaningless if both the unbound and membrane bound isozymes of acid phosphatase were not accounted for. Since the unbound isozymes could be easily assayed, Triton X-100 was selected to release those isozymes bound to membranes within the cells. Depending on the method of introduction and concentration of the detergent used, no more than 3% of the total acid phosphatase present in P. silusiae was found to be bound by membranes, meaning 97% of the enzyme could be assayed without the use of Triton X-100. Therefore, the amount of bound acid phosphatase was considered negligible.

The results of the electrophoretic/densitometric studies indicate that there is a relationship between acid phosphatase levels and age in P. silusiae. The changes exhibited by acid phosphatase appear to be related to development and aging, and these changes probably result from the involvement of several molecular species (isozymes) of the enzyme.

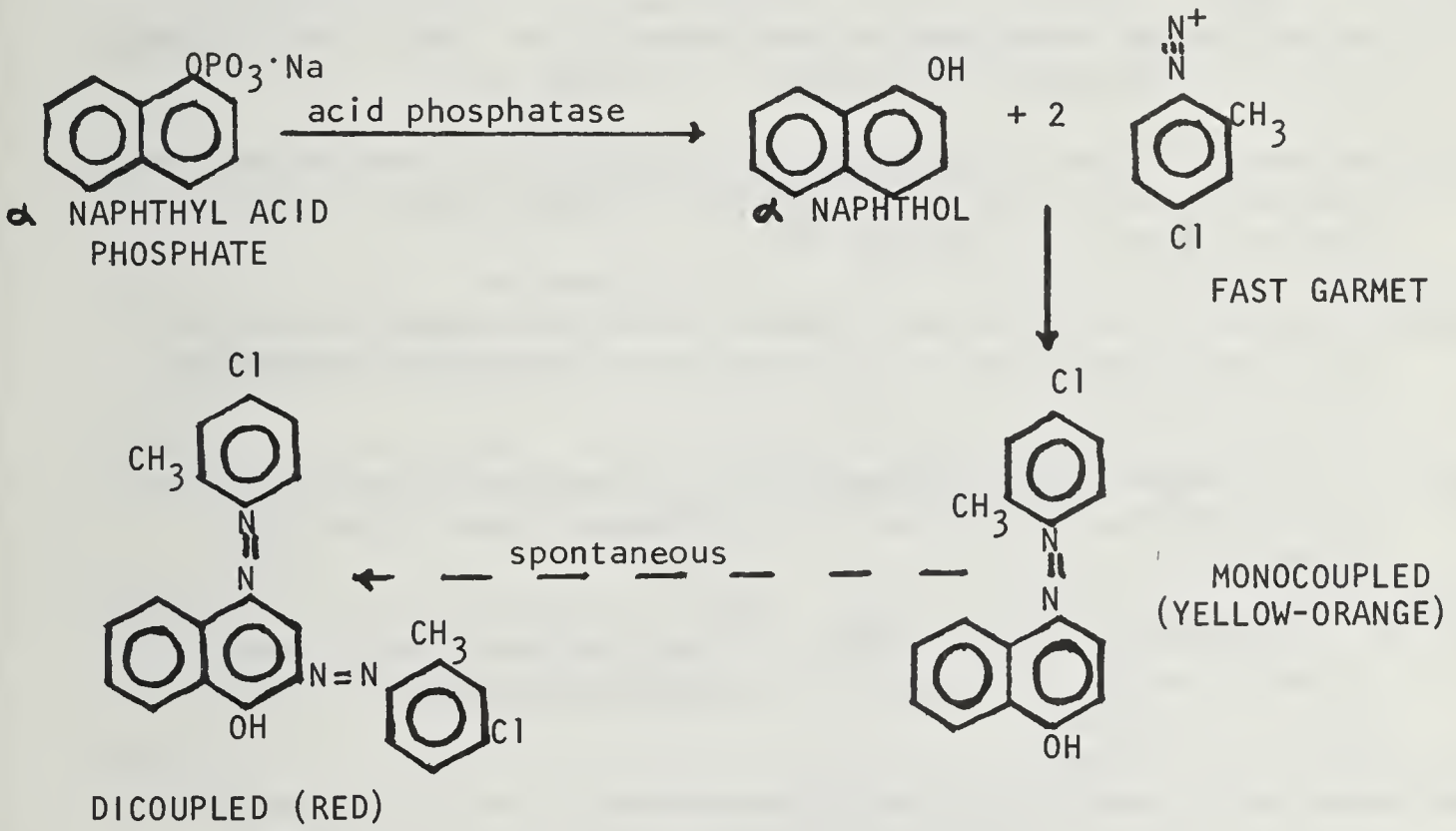
By studying Table 2, it can be seen that isozymes 1, 3, and 5 were only present in the adult stages, indicating they may be connected with the onset of senescence. Isozyme 2 appeared only in the larval stages, indicating involvement with the development of the nematode, instead of the actual aging process. Because isozyme 4 was only present in the L_2 stage, it seems to be related to some early development in the young larvae. Isozyme 6 was present throughout the entire life cycle. Its relative activity peaked in the L_4 stage, dropped by 80% in the molt to the L_5 stage, and continued to drop during the rest of the life cycle, indicating a greater involvement with development than with aging. Perhaps it is involved with the onset of gonadogenesis, since its activity peaks during the stage when this process begins. The 7th isozyme was present briefly in the middle of the life cycle, indicating it is involved with the onset of development of some particular structures and disappears upon their completion. The 8th isozyme may be involved with the final aspects of aging just prior to death, since it appeared only in the 25-day-old nematodes. Isozyme 9 may be connected with the aging process, since its relative activity peaked in the 15-day-old worms. The 10th isozyme, which travelled beyond the tracking dye, may be involved in both development and aging, since it was present in every stage of the life cycle.

The number of isozymes of acid phosphatase increases with age in P. silusiae, but the relative activities of the different isozymes peak at different stages, while the overall enzyme activity decreases with age. Apparently, it is not the relative activity that is related to senescence, but the particular isozymes present. These results are consistent with the findings of Erlanger and Gershon (1970) on T. aceti and Bolla et al. (1974) on N. brasiliensis, who concluded that these biochemical changes correlate with the morphological and physical changes that occur during the stages of development and aging throughout the nematode's life cycle.

The isozyme bands on the electrophoretic gels appeared either red, faint red, or yellow in color. The difference between the two shades of

red is explained by the fact that those isozymes that stained faint red were always of a lesser activity than those that stained red on the same gel, indicating that there was less of each faint staining isozyme than of those which stained darker. The yellow bands are explained by MacIntyre (1971) who studied the staining reactions used in this research (Figure 1). He found that acid phosphatase stains yellow if there is a lack of spontaneity in progressing from a yellow, monocoupled colored complex to a red, dicoupled colored complex.

FIGURE 1: CHEMICAL REACTIONS INVOLVED IN THE STAINING PROCESS



From the light microscopic study, it can be seen that the L_2 and L_3 stages show very little staining for acid phosphatase, indicating a low activity of the enzyme. However, the electrophoretic/densitometric studies indicated high levels of activity, but few isozymes at these stages. Perhaps some isozymes may not be stained by the histochemical technique used. Due to these somewhat conflicting results, further study of these two larval stages is necessary. Complete staining of the gastrointestinal tract and developing gonads was obvious in the L_4 stage. In the adult stage, the digestive tract, excretory canals, reproductive system, and eggs and unborn L_1 worms in the bodies of mature females all stained positively for acid phosphatase. This microscopic study therefore indicates that acid phosphatase is present in high concentrations in the digestive, excretory, and reproductive systems of P. silusiae, which is consistent with previous findings in other nematodes (Cesari, 1974).

Cristofalo et al. (1967) hypothesized that with increased age, acid phosphatase activity gradually shifts the equilibrium in the cell away from synthesis and towards catabolism, thus resulting in a general deterioration of the cells. This research seems to lend partial support to that hypothesis, for the data obtained indicates that there is a specific change in the isozymes of acid phosphatase which corresponds to the stages in the aging process, and thus acid phosphatase activity clearly varies with age.

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ANALYSIS OF THE FREE AMINO ACID COMPOSITION OF THE HEMOLYMPH OF THE DARKLING BEETLE, TENEBRIO MOLITOR (COLEOPTERA : TENEBRIONIDAE)

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ABSTRACT. - The hemolymph of the tenebrionid beetle, Tenebrio molitor, a common species of Illinois, was analyzed with respect to free amino acid composition in the larval, pupal, teneral adult and adult stages. Asparagine, phenylalanine, leucine and isoleucine were found in very small concentrations. Lysine, methionine, threonine and tyrosine were found in slightly higher concentrations. Glycine, valine, alanine, histidine and arginine were the principal free amino acids of the hemolymph of this species. This represents the first available data on hemolymph free amino acid concentrations for this species of Coleoptera with respect to developmental stage.

INTRODUCTION

Previous investigations concerning the amino acid composition of the hemolymph of Coleoptera have concentrated on relatively few species (Florkin and Jeuniaux 1974; Punzo 1977). Quantitative analyses have been performed on Popillia japonica (Shotwell et al. 1963), Hydrophilus decemlineata and Leptinotarsa decemlineata (Duchateau and Florkin 1958). However, these studies represent analyses of only one developmental stage of the life cycle. Reviews concerning the general composition of insect hemolymph (Florkin and Jeuniaux 1974; Jeuniaux 1971; Wyatt 1961) and free amino acid (FAA) composition (Chen 1962, 1966; Duchateau and Florkin 1958) are available, but only a few represent developmental studies (Barrett 1974; Boctor and Salem 1973; DeBianchi and Terra 1976; Wirtz and Hopkins 1974).

One of the characteristics of insect hemolymph is the presence of high concentrations of FAA (Duchateau nad

Florkin 1958; Florkin and Jeuniaux 1974; Sutcliffe 1963). This is especially true of endopterygotes where the high concentration represents an evolutionary trend separating them from the exopterygote insects and other Arthropoda (Sutcliffe 1963). In endopterygotes, total FAA concentrations are generally above 700 mg/100 ml, whereas in exopterygotes FAA concentrations are below this level (Jeuniaux 1971).

The high level of FAA have a number of functions in insect hemolymph including protein synthesis, osmoregulation and intermediary metabolism (Chen 1958, 1962). FAA may also provide a buffering effect as well as a role in detoxification processes (Chen 1962, 1966).

The purpose of the present study was to determine the FAA composition of the tenebrionid beetle, Tenebrio molitor, a common species found in Illinois which frequently becomes a pest of stored grain products (Ernst and Mutchmor 1969) throughout North America. Since little FAA information is available from a developmental point of view, and no data available for Coleoptera, the various life cycle stages of this holometabolous insect were analyzed for FAA concentrations.

MATERIALS AND METHODS

The insects utilized in this study were obtained from a laboratory stock culture maintained at room temperature. The beetles were maintained on Ralston wheat cereal and corn meal (1 : 1 ratio) with potato slices added to the rearing cages for moisture. The laboratory colony was initiated with beetles collected in Macoupin County, Illinois. Species identifications were confirmed by the Entomology Museum, Iowa State University, Ames, Iowa.

FAA analyses were conducted on the larval, pupal, teneral adult and adult stages of T. molitor. The larvae were divided into two developmental stages differentiated on the basis of larval length (Ernst and Mutchmor 1969) and weight (Mellanby 1932): young larvae ($<$ 30 mg; 6-12 mm) and old larvae ($>$ 100 mg; 25-30 mm).

The procedure used to collect hemolymph was similar to that reported by Punzo (1977). An incision was made over the dorsal aspect of the thorax and 1-2 µl of hemolymph were collected from each specimen by aspiration with a glass micropipette. The hemolymph from 5-10 insects was pooled for analysis for each developmental stage. FAA analyses

were obtained by a method similar to that reported by Nair and Prabhu (1971). The collected hemolymph was deproteinized in 80% ethanol and centrifuged for 10 min at 1500 rpm. The protein-free supernatant containing the FAA was evaporated to a residue at 60 deg C. This was analyzed as total ninhydrin-positive material against a glutamic acid standard at 570 mμ on a Bausch and Lomb Spectronic 20 spectrophotometer. Two-dimensional TLC was performed on silica gel-G plates using chloroform-ethanol-ammonia (2:2:1 v/v) in one direction and phenol-water (75:25 w/w) in the other. Individual amino acid spots were visualized with ninhydrin reagent and identified by their R_f values. Chromatograms were scanned in a Photovolt Corporation Densicord Densitometer and the concentrations of individual amino acids were calculated from the densitometric chart and the total FAA concentration.

RESULTS AND DISCUSSION

The results of the FAA hemolymph concentrations in Tenebrio molitor are shown in Table 1. The relative wide range of individual values should be noted, especially with alanine during the pupal stages. Though FAA concentrations can vary considerably depending on the species, taxonomic group, and physiological state of the organism, some generalizations have been made (Agrell and Lundquist 1973; Florkin and Jeuniaux 1974; Jeuniaux 1971). Asparagine, phenylalanine, leucine and isoleucine have been found to contribute relatively little to the total FAA concentration (Florkin and Jeuniaux 1974; Sutcliffe 1963). The results obtained for T. molitor in this experiment confirm this for this family of Coleoptera. Glutamic acid and proline, though not as abundant as other amino acids, are important metabolic intermediates in the FAA pool (Chen 1966; Florkin and Jeuniaux 1974; Patterson 1957; Sacktor 1974). Other important FAA are glycine, valine, alanine, histidine and arginine. These were found in substantial concentrations in T. molitor. Lysine, methionine, threonine and tyrosine were found in relatively low concentrations (Table 1). This is in agreement with previous investigations on FAA concentrations in other insect groups (Chen 1962; Duchateau and Florkin 1958; Jeuniaux 1971; Shotwell et al. 1963; Wyatt 1961).

The aminoacidemia of an insect species has been described

TABLE 1. The free amino acid composition of the hemolymph of *Tenebrio molitor*. Values are expressed in mg/100 ml.

Amino Acid	Young Larvae	Old Larvae	Day 1 Pupae	Day 2 Pupae	Day 3 Pupae	Day 4 Pupae	Day 5 Pupae	Teneral Adult	Adult
Ala	137-175	151-189	24-201	37-163	51-139	49-147	61-159	52-84	43-119
Arg	39-83	43-77	27-68	41-70	43-81	39-83	44-80	51-77	36-61
Asp	32-53	39-49	17-41	22-38	27-39	19-36	25-34	26-31	17-25
Glu	284-513	267-501	217-418	226-393	211-408	217-490	247-513	190-221	119-137
Gly	222-341	263-303	241-280	212-267	194-233	240-273	181-209	71-98	47-56
His	158-206	147-192	97-141	103-152	116-138	101-141	84-111	67-82	39-53
Iso	38-57	42-63	18-32	11-24	16-30	14-23	8-17	6-14	4-9
Leu	27-40	26-34	15-21	19-28	21-26	11-17	7-16	5-10	3-7
Lys	32-92	24-88	17-62	27-58	31-51	20-37	23-34	19-34	17-25
Met	6-17	5-14	7-11	11-19	6-15	6-12	7-17	6-11	3-5
Phe	10-15	11-18	9-14	11-16	13-20	7-15	9-13	8-15	5-9
Pro	231-480	248-493	227-481	266-407	202-291	187-216	87-116	43-74	39-62
Thr	13-21	11-27	10-16	14-26	12-24	12-28	11-29	12-19	11-27
Tyr	10-21	13-23	11-15	10-17	12-19	10-18	11-16	8-13	7-11
Val	91-139	86-143	77-116	84-140	95-139	89-131	91-144	78-130	51-118

as being a succession of steady states which are related to a number of events including the developmental stage and the physiological state of the insect (Agrell and Lundquist 1973; Florkin and Jeuniaux 1974; Punzo 1977). The results in Table 1 show that the amino acid patterns change only slightly during the life cycle. One exception to this is proline, which decreases greatly in proportion to the rest of the amino acids from fourth to fifth day pupae. Other exceptions are arginine and valine which increase in proportion to the other amino acids throughout the life cycle.

One of the more notable features of Table 1 is the steady decrease in total FAA concentration with increasing age. This trend is especially noticeable between the pupal and teneral adult stages. Similar findings have been reported for other holometabolous insect orders including the Hymenoptera (Florkin and Jeuniaux 1974; Jeuniaux 1971) and Lepidoptera (Chen 1962; Duchateau and Florkin 1958; Florkin and Jeuniaux 1974; Sutcliffe 1963). There is also a significant decrease in total FAA between the larval and adult stages (Table 1). This decrease is related to the fact that following pupation, the organism represents a relatively closed system with FAA being utilized from the hemolymph amino acid pool by incorporation into protein (Agrell and Lundquist 1973; Jeuniaux 1971; Sacktor 1974). This suggests that the large FAA pool in larvae may function as an amino acid resevoir that can be utilized during the histogenic phase of metamorphosis.

The concentration of FAA in pupae has been described as a balance between histolysis and histogenesis with amino acids produced by histolysis being used immediately in the synthesis of new proteins (Chen 1966). With this in mind, it is not surprising to find little major fluctuation in total FAA concentration during the pupal stages of *T. molitor* (Table 1) and in the FAA pattern despite the drastic morphological changes that occur during metamorphosis. This stability of the FAA pattern has been reported for several holometabolous insects (Chen 1966; Florkin and Jeuniaux 1974; Patterson 1957; Sacktor 1974), and has now been substantiated for this species of Coleoptera.

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LACK OF PHYSIOLOGICAL DIFFERENTIATION IN THREE COLOR MORPHS OF THE CRICKET FROG (*Acris crepitans*) IN ILLINOIS

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ABSTRACT

Physiological differences among color morphs on which selection might act to maintain the balanced polymorphism in the cricket frog (*Acris crepitans*) were evaluated. CTM, desiccation rates, resistance to prolonged stress and thermal preference, showed no significant differences among red, green or gray striped frogs from the same populations in Illinois.

INTRODUCTION

The genetic basis of inheritance is known for several cases of color and/or pattern polymorphism in amphibians. However, factors which determine morph frequency have been the subjects of much speculation including: 1) Mayr's (1942) founder principle and genetic drift (Goin, 1947), 2) visual selection by predators (Goin, 1947; Pyburn, 1961a: Mathews, 1971; Nevo, 1973; Stewart, 1974) including apostatic selection (Milstead et al., 1974), 3) selection for a behavioral characteristic associated with a particular morph (Wendelken, 1968), 4) selection for an associated physiological factor (Goin, 1947; Test, 1955; Main, 1961, 1965; Merrell and Rodell, 1967; Dasgupta and Grewal, 1968; Williams et al., 1968; Nevo, 1973), or 5) a combination of chance, visual selection by predators and physiological factors acting in concert (Jameson and Pequqnat, 1971; Nevo, 1973). Mathews (1971) pointed out that during the aquatic larval stage selection would have to act at the physiological or behavioral level, since adult color phases have not developed. Thus, the trend has been to attribute the adaptive value of amphibian color morphs to certain cryptic physiological or behavioral differences which may be controlled by pleiotropic genes. However, there is little or no conclusive evidence that adaptive differences actually exist.

The cricket frog, *Acris crepitans*, exhibits a genetically based color polymorphism in which green stripe is dominant to the nongreen condition (i.e., red stripe or gray) and red stripe is dominant to gray (Pyburn, 1961a, 1961b). The species has a geographical distribution extending from northeastern Mexico to southern Wisconsin and east to the Atlantic Coast. Thus, it is adapted to many different local conditions of temperature and moisture ranging from semidesert to swamp. Any demonstration of the adaptive or nonadaptive (neutral) value of the

three color morphs of Acris would provide interesting insights into the concept of amphibian polymorphism. This study investigated possible physiological morph differences upon which selection might act to maintain the balanced polymorphism in Acris crepitans. Frogs were collected from central and southern Illinois and critical thermal maxima (CTM), desiccation rates, resistance to prolonged stress, and thermal preference of the three morphs determined.

MATERIALS AND METHODS

Critical Thermal Maxima

CTM was determined for each morph using a modification of the method of Brattstrom (1968). Frogs of similar size were collected in fall from the La Rue Pine Hills Swamp (southern Illinois) in Union County, 8 miles southeast of Grand Tower, and the Mackinaw River (central Illinois) in McLean County about 10 miles northeast of Normal, and maintained at room temperature (22-23°C) on a diet of fruit flies for 1 week. After acclimation, a Yellow Springs Instrument Company (YSI) temperature probe (Model 43 TZ) was inserted into the cloaca of each frog (8-20 of each morph, Table 1). The animal was then placed in a glass bowl (80 cm dia, 3 cm deep) filled with 5 mm of water. The bowl was covered with a glass lid to prevent desiccation. The chamber was heated (about 1°C/min) by an overhead heat lamp 30 cm above the bottom of the bowl. The "onset of spasms" (Hutchison, 1961; Hutchison et al., 1966) or temperature where control of normal body movements was lost (i.e., behavioral or ecological death) was recorded as the CTM. The frog was then immediately placed in cool water and revived. Unrevivable frogs were considered to have reached physiological death and were not included in the results. Thus, the CTM reported is not to be confused with upper lethal temperature, as it preceeds physiological death.

TABLE 1. COMPARISON OF PHYSIOLOGICAL ATTRIBUTES OF ACRIS CREPITANS MORPHS FROM CENTRAL AND SOUTHERN ILLINOIS

Collection Site	Red	Gray	Green	F Values[1]
Critical Thermal Maxima (°C)				
Mackinaw River	38.8±1.2 (20)[2]	38.8±1.2 (20)	39.5±1.2 (10)	0.70
Pine Hills	39.0±1.0 (10)	39.0±0.8 (10)	39.1±0.9 (10)	0.06
Desiccation Rates (mg H_2O lost/min/g tissue)				
Dawson Lake	1.30±0.11 (10)	1.19±0.11 (10)	1.26±0.11 (10)	0.42
Pine Hills	1.39±0.12 (10)	1.38±0.11 (10)	1.46±0.10 (10)	0.21
Thermal Preference (°C)				
Dawson Lake	26.9±2.2 (16)	27.2±2.8 (19)	28.0±2.8 (15)	0.65
Pine Hills	27.5±2.8 (10)	28.5±3.7 (15)	28.2±3.1 (15)	0.31

1 not significant.
2 (sample size).

Desiccation Rates

Desiccation rates for each morph (10 frogs/morph/location, Table 1) were obtained at room temperature using acclimated frogs collected during spring at Pine Hills and Dawson Lake (central Illinois) in McLean County, 15 miles southeast of Bloomington, IL. Two half-pint bottles filled with desiccant (Filtrol Corporation Desiccite No. 25) were placed in the corners of a closed weighing chamber (Sartorious balance, Type 2703) to absorb moisture. Urinary bladders were emptied and frogs were placed in a small screen cage (5 x 2.5 x 2.5 cm), suspended from the hook which supports the weighing pan of the balance. After an equilibrium period of 15 min, an initial weight reading was taken. This was followed by six subsequent readings 5 min apart. The weight of water lost in each 5 min period was determined by substraction and converted to mg water lost/min/g of tissue.

Resistance to Prolonged Stress

The ability of morphs to withstand prolonged exposure to five types of stress (heat, cold, desiccation, moisture, and starvation) was tested in six 10-gallon aquaria arranged as follows: The bottom of the control aquarium (No. 1) was covered with 3 cm of soil and a small glass bowl (15 cm dia, 3 cm deep) of water was buried to its rim in the center. Sixty *Acris crepitans* (14 red, 26 gray and 20 green) were toe clipped according to color as a check against metachrosis (Gray, 1972) and placed in the aquarium, which was covered with cheesecloth. Frogs were supplied fruit flies every other day, and maintained at room temperature (22-23°C) on a 8:16 light:dark cycle, during the experiment. The remaining five aquaria were set up in essentially the same fashion using the same numbers of each morph but differed as follows: Aquaria No. 2 and 3 were maintained at 37 and 2°C respectively. Aquarium No. 4 contained two half-pint bottles filled with disiccant (Filtrol Corporation Desiccite No. 25) and no water. Aquarium No. 5 was covered with a plastic sheet which maintained the relative humidity at 86-93% (measured with an Atkins Thermistor Psychrometer, Model 3202B). Frogs in aquarium No. 6 were not fed. The aquaria were checked at least four times daily until all frogs were dead. The time of death of each animal was recorded to the nearest hour.

Adequate numbers of all color morphs could not be obtained from the same area for these experiments. Red striped frogs were collected at Six Mile Creek in Woodford County, 8 miles northwest of Normal, IL, and gray and green striped frogs were collected at Dawson Lake, both in central Illinois. After results from aquarium No. 3 were known, the experiment was repeated using 20 red and 20 gray striped frogs from Six Mile Creek to determine if the initial differences found were among morphs or between populations.

Thermal Preference

Thermal preference of each morph was tested in an elongated metal box (86 x 10 x 10 cm) with plastic top. The box floor was lined with moist paper towels to prevent frog desiccation. Thermometers were inserted through the top at 3 cm intervals with the bulbs resting on the paper towels. A 100 watt bulb was placed in one end of the box, which was placed over three hot plates to establish a heat gradient from 20 to 49°C. Frogs (not used in previous experiments) from Pine Hills and Dawson Lake were placed on the towels and after 15 min, the temperature of the thermometer nearest an animal was recorded to the nearest 0.5°C.

Statistical Analysis

Values obtained for CTM, desiccation rate, resistance to prolonged stress and thermal preference, were grouped according to color class. Differences among and between morphs were tested for statistical significance by analyses of variance and the student's t test respectively.

RESULTS

Results of CTM, desiccation rate and thermal preference studies are summarized in Table 1. In each experiment, mean values reported are based on sample sizes of 10 or more. No significant differences were found among morphs from central or southern Illinois populations.

Results of prolonged stress studies (i.e., heat, cold, desiccation, humidity and starvation) also failed to reveal significant differences among morphs from the same population (Table 2). However, the cold stress experiment initially revealed significant differences and the Newman-Keuls Test (Winer, 1962) indicated death times of red striped frogs were higher than those of green striped frogs. When the experiment was repeated (Table 2, aquarium 2a), using red and gray morphs from the same population, no significant difference was apparent. Since death times of gray and green striped frogs from Dawson Lake were similar, the initial differences were probably between populations and not among morphs.

TABLE 2. RESISTANCE TO PROLONGED STRESS OF *ACRIS CREPITANS* MORPHS FROM CENTRAL AND SOUTHERN ILLINOIS

Aquarium No.[1]	Type Stress	Mean Survival (hr) Red	Gray	Green	F Values
1	Control	483±387	248±181	344±496	1.94
2	Heat (37°C)	703±208	697±309	561±205	1.93
3	Cold (2°C)	1061±482	808±358	702±346	3.65[2]
4	Desiccation	176±13	184±12	180±12	2.38
5	Humidity	589±387	687±480	522±233	0.93
6	Starvation	289±132	264±301	307±350	0.13
2a	Cold (2°C) Repeat	807±211	749±233		0.24[3]

1 sample size in aquaria 1-6 was 14 red, 26 gray and 20 green; sample size in aquaria 2a was 20 red and 20 gray.
2 $p<.05$.
3 students t test--not significant.

DISCUSSION

In *A. crepitans*, Pyburn (1961a) suggested visual selection by predators directly determined color pattern frequencies. Wendelken (1968), disagreed with Pyburn's visual selection hypothesis and stated selection may favor some behavioral characteristic associated with a particular morph. Nevo (1973) favored the visual selection hypothesis but presented

evidence that selection may also act on morph associated physiological factors. Milstead et al. (1974) hypothesized apostatic selection as another means of maintaining the balanced polymorphism in A.crepitans.

Although Nevo (1973) found gray morphs from Texas were more resistant to desiccation than red morphs I could find no differences in desiccation rate and other physiological parameters in Illinois populations. It seems unlikely genes controlling Acris color polymorphism are nonadaptive or of neutral survival value. However, the lack of morph differences in CTM, desiccation rate, resistance to various types of prolonged stress and thermal preference eliminates a number of factors that might act differentially to maintain the balanced color polymorphism of Acris in Illinois. Different selective mechanisms may be operating in different geographical regions. Selective value of color and pattern variations and the extent of physiological and behavioral differences among morphs must be ascertained throughout the range of A.crepitans to understand the adaptive value of this polymorphism.

ACKNOWLEDGMENTS

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BIOPOLYMER FORMATION BY ACTIVATED SLUDGE IN THE PRESENCE OF METHANOL

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ABSTRACT

Activated sludge from four municipal waste disposal plants contained microorganisms which produced a viscous product when aerated with added methanol. Activated sludge from an industrial corn products firm made heteropolysaccharides only if acid was repeatedly neutralized. The influence of aeration, backseeding, and time of methanol feeding on viscosity and methanol utilization was examined in four 10-liter fermentations for 7 days. After methanol depletion, viscosity declined. Readily soluble, freeze-dried crude products were prepared. The crude product mixed with fertilizers or pesticides was shown, by other investigators, to have some promise as a slow-release agent.

INTRODUCTION

Previous work in our laboratory (Davis and Wallen, 1976) has demonstrated that mixed cultures of organisms in activated sludge (AS) from a waste treatment plant, when aerated with low concentrations of methanol, will produce a highly viscous crude product containing glycan polymer. During the course of a week-long fermentation, activity of biopolymer-producing organisms is enhanced by the presence of methanol. The addition of some of the final product from a recent methanol fermentation as backseed to fresh AS results in a more rapid fermentation with a more efficient conversion of methanol to polymer. Data previously reported were obtained mostly with AS from the waste treatment plant of the Greater Peoria (IL) Sanitary District. Fermentations were conducted in Fernbach flasks using 500 cc aliquants and rotary shaker aeration.

Results from the use of the AS from three additional smaller municipal plants and one agribusiness experimental waste treatment plant are reported here. Also reported are four fermentations in 10-liter quantities to study variables which are controllable only in such fermentors.

MATERIALS AND METHODS

Comparison of Activated Sludges

Approximately 3-liter samples of AS were taken from the municipal waste treatment plants in (1) Peoria, (2) Pekin, (3) East Peoria, and (4) Washington, Illinois, and (5) from the experimental waste processing unit of a corn starch-dextrose manufacturer. The Peoria plant processes about 30 million gallons per day, the others about 1 million or less. Within 3 hr of collection, 500 ml aliquants of these AS samples were placed in nonsterile 2800 ml Fernbach flasks and 5 ml methanol (ACS grade) was added (1% v/v). A duplicate series received 450 ml AS plus 50 ml of 5-day fermentation material from Peoria AS as backseed. The flasks were incubated at 25 C on a rotary shaker at 200 rpm. An additional 5 ml methanol was added after 1 day and 10 ml after 2 days for a total of 4% (v/v). Small samples were withdrawn each day for determination of pH and viscosity.

Ten-Liter Studies

Results obtained in laboratory-scale equipment cannot always be duplicated in commercial-size fermentations. Therefore, a series of 10-liter fermentations were run in identical 20-liter capacity fermentors using conditions found effective in flask fermentors. Three variables were tested: backseeding, timing of methanol additions, and degree of aeration. The backseed was 4-day fermentation material from flask fermentations. Antifoam was not required. Ten gallons of Peoria AS was collected at 8 a.m. and screened through double cheesecloth. Ten liters AS was put in one nonsterile fermentor, and 9.5 liters AS plus 500 ml 5-day backseed was used in each of three other fermentors. The protocol is given in the legend of Figure 1. Five-hundred ml aliquots were withdrawn into sterile Fernbach flasks as controls from two set fermentors. These flasks were incubated on a rotary shaker at 25 C with 2% additional methanol added after 2 days. Samples were taken daily, and pH and viscosity were determined immediately; small samples were frozen for later assay of residual methanol. About 4 liters of 7-day products from two fermentors were freeze-dried in trays in a Model 25-SRC-3 Virtis Sublimator.

Analyses

pH was determined by glass electrode. Viscosity (in centipoises) was determined with a Brookfield Viscometer (Model RVT, No. 4 spindel, 30 rpm at 25 C) by averaging several measurements in different locations in each sample. Residual methanol was determined by gas-liquid chromatography. Five or 10 microliters of thawed supernatant was injected in replicate. Volume percent concentration was calculated by comparing peak area to a standard.

RESULTS

Comparison of Activated Sludges

Table 1 shows that all of the municipal treatment plants

Table 1. Methanol Fermentations by Activated Sludge from Different Treatment Plants

Plant	Days	Activated Sludge		Act. Sl. + 10% Backseed	
		pH	Viscosity (cp)	pH	Viscosity (cp)
Peoria	4	7.2	2996	7.3	7464
Pekin	4	6.9	3196	7.2	5324
East Peoria	4	7.0	1708	7.3	6212
Washington	4	7.3	1006	7.3	7452
Agri-					
business	3	4.9(6.9)*	0	6.3(7.2)*	2370
(corn	4	5.3(6.7)*	1364	6.6(6.9)*	3904
starch)	6	5.1	3354	6.7	2722

* Neutralized with NaOH

sampled contain organisms capable of converting methanol to viscous product. All gave comparable responses to methanol-acclimated backseed and showed little variation in pH throughout the time cycle. Two of the AS samples without backseed had a longer lag period in initiating polymer formation and thus required more methanol. These two matched the others when reinforced with backseed.

Previous attempts to form biopolymer with "clarifier underflow" (AS) from the waste treatment facilities of a corn processing plant resulted in failure. Five-day acidities were pH 4.5 or below. Backseeding with Peoria beer gave similar results, i.e., only slight viscosity and slightly higher final pH. This AS did become viscous when the accumulated acid was neutralized daily as shown in Table 1. Backseeding promoted rapid utilization of methanol as judged by viscosity at comparable times. The decrease in viscosity after 4 days may have coincided with depletion of the methanol, as indicated by subsequent experiment.

Ten-Liter Fermentations

Figure 1 shows curves of viscosity and methanol utilization over the 7-day fermentation period. For unknown reasons, AS without backseed (Fig. 1a) did not convert methanol to viscous polymer as efficiently in the 10-liter fermentation as in the shaken flask control. The aliquot in the flask gave viscosities expected from previous experience.

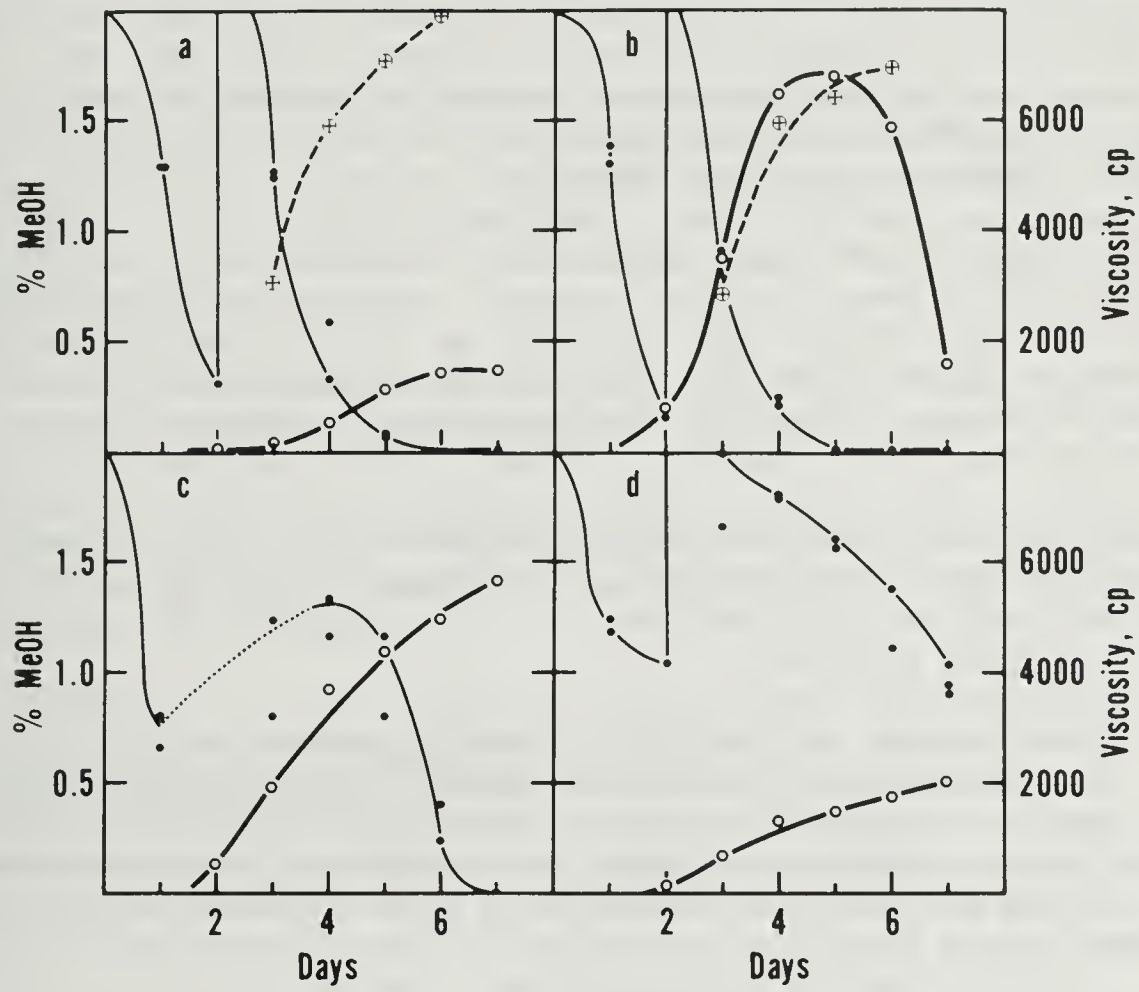

Figure 1. Ten Liter Fermentations with Peoria Activated Sludge (4 day backseed, 25°C, 200 RPM)

Ferm.	5% Backseed	% MeOH added at 0	1	2 days	Aeration lit./min.
a	none	2	0	2	15
b	yes	2	0	2	15
c	yes	1	3*		15
d	yes	2	0	2	2.5

* 0.05% each hour, 24 thru 84 hours

•——• % Methanol
○——○ Viscosity (cp) - Pilot Plant
+---+ Viscosity (cp) - Control Flasks

With backseed added (Fig. 1b), control flask and 10-liter fermentation viscosities paralleled each other. The methanol was utilized faster than without backseed and resulted in higher viscosity product. Biopolymer formation, as judged by increased viscosity, tapered off as methanol approached low concentration. A decrease in viscosity occurred after the exhaustion of methanol. The air to this fermentor was cut off after 6 days, but this did not retard further degradation of viscosity during the next 24 hr. No glucose was found by glucose oxidase test (TESTAPE) in degraded samples during this period.

Essentially continuous addition of methanol (Fig. 1c) prolonged its utilization over the 7-day period. Accumulated biosynthesis gave about the same maximum viscosity as in the fermentation with only two additions (Fig. 1b) of methanol. Again, the increase in viscosity began to taper off as the methanol approached low concentration.

With a critically low rate of aeration (Fig. 1d), methanol was not as rapidly metabolized. Only three-fourths of the 4% added methanol was utilized over the 7-day period with a very low rate of polymer synthesis.

Solids content of the high viscosity product was 1.75% (Fig. 1c) and 2.05% in the lowered viscosity product (Fig. 1b). When these freeze-dried products were resuspended to the original concentrations some months later, viscosities of smooth suspensions were 1795 cp and 608 cp as compared to 5646 cp and 1536 cp in the original liquid products.

DISCUSSION

No biopolymer has been isolated from the viscous product and no proof was found that methanol is necessarily the precursor of viscous products. However, it was previously reported that glucose comprised about three-fourths of the reducing sugars found in an incomplete acid hydrolysate of viscous product. Papergrams of this hydrolysate showed compounds with the R_f of glucose and of oligosaccharides. Also previously shown, viscosity increases only in the presence of methanol and not with other alcohols or sugar. It is a reasonable assumption that some of the organisms present in AS convert methanol to heteropolysaccharides as found by Ballerini and Parlouar (1974) and Finn et al. (1975, 1976) with other organisms.

The viscosity exhibited by the heteropolysaccharides in admixture with AS solids must be due to the composition of the biopolymer, the amount of polymer formed, the length of the polymer chains or the physical aggregation of the chains, or a combination of these. No glucose was found in samples taken during the period when viscosity was decreasing rapidly. If free

glucose is released when viscosity drops, the organisms may have utilized it as fast as it formed. Or, chain shortening may have occurred by enzymatic breaking of internal bonds. If it is inconvenient to harvest at the time of maximum viscosity, the biopolymer may apparently be stabilized by addition of methanol to maintain a low concentration.

Automatic continuous addition of methanol might be convenient in large-scale operations and may give the most efficient utilization of substrate. However, improper feeding rates could result in continuous low levels of methanol concentration, and there is some evidence that such low methanol concentrations give low yields of polymer.

When a suspension of thick or diluted AS-methanol fermentation product is spread or sprayed on a surface, evaporation of water leaves a friable film which is not easily redispersed or displaced by water. This property has been utilized by others in our laboratory to prepare admixtures of fertilizers or pesticides in which the viscous product acts as a slow release agent (Roth, 1977).

Fermentative production of polysaccharides from methanol by the soil isolates Achromobacter sp. (Ballerini and Parlouar, 1974) and Methylamonas mucosa (Finn et al., 1975, 1976) have been reported. These organisms were grown in sterilized semi-synthetic media in pure culture. Activated sludge, in contrast, permits a nonsterile fermentation with a self-selected mixed culture as shown in a previous paper. The starting material is constantly available and requires only the addition of methanol and air. Open tanks, such as the aeration bays of waste treatment plants, should make satisfactory fermentors. The product is pumpable, and retention of a small fraction of the fermented product in the fermentor would be convenient as backseed for the next fermentation.

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DISTRIBUTIONAL RECORDS OF POLYGYRID SNAILS IN ILLINOIS WITH AN ADDITION TO THE STATE FAUNA

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ABSTRACT

Locality records are listed for Polygyra dorfeuilliana, Stenotrema hirsutum, S. fraternum, Mesodon thyroidus, M. zaletus, M. pennsylvanicus, M. elevatus, M. inflectus, Triodopsis discoidea, T. fraudulenta vulgata, T. notata, T. albolabris, T. multilineata, T. divesta and Allogona profunda. The first Illinois record of Ozarkian Triodopsis divesta is reported from Monroe Co.

Baker (1939) published the most recent comprehensive account of the polygyrid snail fauna of Illinois. Except for rarer species, Baker (1939) listed few specific locality records and presented only generalized statements of polygyrid distributions in Illinois. Consequently, specific records of many Illinois polygyrids are not widely available. Most early records (many later cited by Pilsbry, 1940) are based on shell characters, however Pilsbry (1940) and many subsequent authors have shown that anatomical details, especially of the terminal genitalia, are more reliable indicators of relationships than are shell characters. In order to make specific records of anatomically determined snails available to other workers, this paper presents a listing of all polygyrid snails collected in Illinois during 1976 by the authors.

One to several specimens of each species from each locality where possible were dissected. Voucher specimens of all species and from nearly all localities are in the Field Museum of Natural History. Records for common widespread species are simply listed. Habitat notes and other comments are presented for less commonly encountered species. At many localities more than one species of polygyrid snails were collected. Each locality is numbered and given in full the first time it appears below. Only the locality numbers are given for subsequent entries.

RECORDS

Polygyra dorfeuilliana Lea

1. 19 May 1976, wooded bluffs along Fults Rd., 3.7 km SSE Valmeyer, Monroe Co.

Stenotrema hirsutum (Say)

2. 8 May 1976, under logs along banks of Mackinaw River, 7.2 air km N Hudson, McLean Co.

3. 14 May 1976, on logs, Funk's Grove, McLean Co.
4. 17 Aug. 1976, E bank Kaskaskia River, 2 km E Cowden, Shelby Co.
5. 23 May 1976, fence row and creek bordering Herald rd., 1.6 km N Ill. Hwy. 141, White Co.
6. 21 May 1976, Wolf Lake swamp, Union Co.

Stenotrema fraternum (Say)

7. 2 May 1976, vacant lot near jct. U. S. Hwy. 40 and Ill. Hwys. 32-33, Effingham, Effingham Co.
8. 3 May 1976, cemetery at jct. Wren Dr. and Cardinal Ln., Lake Sara, Effingham Co.
9. 22 May 1976, woods along Ill. Hwy. 146, 3.0 km N Cisne, Wayne Co.
10. 22 May 1976, woods along Bay City Rd., 4.8 km S Golconda, Pope Co.

Mesodon thyroidus (Say)

Locality 5.
11. 16 April 1976, 14 May 1976, on logs, Funk's Grove, McLean Co.
12. 10 April 1976, Moraine View State Park, McLean Co.
13. 7 June 1976, S side Effingham City Resevoir, 1.6 km W jct. Int. Hwy. 57 and U. S. Hwy. 40, Effingham Co.
14. 5 June 1976, below U. S. Hwy. 460 bridge over Wabash River, White Co.
15. 24 April 1976, Wolf Lake swamp, Union Co.
16. 23 May 1976, along Ill. Hwy. 127, 4.8 km S Alto Pass, Union Co.
17. 22 May 1976, S side Horseshoe Lake, Alexander Co.
18. 21 May 1976, woods along Ill. Hwy. 3, 0.8 km NW Thebes, Alexander Co.
19. 23 May 1976, junk pile, NE jct. Miller City Rd. and Ill. Hwy. 3, Alexander Co.

Mesodon zaletus (Binney)

Locality 1. Pilsbry (1940) recorded M. zaletus from Jackson and Madison counties. Baker (1939) reported that the species was most common in eastern and southern Illinois extending north along the Mississippi valley to Calhoun Co. but cited no specific records. Monroe Co. M. zaletus reported here inhabited the forested west facing rocky slopes below rocky bluffs bordering the Mississippi River floodplain.

Mesodon pennsylvanicus (Green)

20. 13 Aug. 1976, fence row near Mahomet exit of Int. Hwy. 74, Mahomet, Champaign Co. Pilsbry (1940) recorded M. pennsylvanicus from Will, LaSalle, Washington, Jackson, Hancock and Fulton counties. Baker (1939) reported that the species is widely distributed in Illinois, being found in ravines where there is a heavy growth of oak, maple, hickory or sycamore trees. The Champaign Co. population that we report was found along an ecotonal area between oak-maple forest and grassland. None were found in the adjacent woods.

Mesodon elevatus (Say)

21. 13 May 1976, wooded ravine bordering Abraham Lincoln Memorial Park, 2.4 km E Charleston, Coles Co. Baker (1939) reported M. elevatus from Fulton, Vermilion, Clark, Lawrence, Madison, Jackson and Alexander counties. In Coles Co. we found this species in a second growth oak-maple woods at the bottom and along the sides of a ravine. All individuals collected were crawling in the open on leaf litter at about 1600 CDT.

Mesodon inflectus (Say)

Localities 1, 14, and 15.
22. 24 May 1976, woods at rest stop on Int. Hwy. 57, 2.3 km S Effingham-Shelby Co. line, Effingham Co.
23. 19 May 1976, woods at Bluff Rd., 1.9 km SE Fults, Monroe Co.

24. 22 May 1976, woods bordering Ill. Hwy. 130, 9.2 km N Albion, Edwards Co.
25. 22 May 1976, woods bordering Ill. Hwy. 1, 2.7 km N jct. Ill. Hwys. 1 and 141, White Co.
26. 22 May 1976, woods bordering Ill. Hwy. 1, 23.7 km S jct. Ill. Hwys. 1 and 141, White Co.
27. 23 May 1976, N side Cave-in Rock State Park, Hardin Co.
28. 22 May 1976, woods bordering secondary rd., 3.2 km W Herod, Pope Co.
29. 22 May 1976, woods bordering Bay City Rd., 4.8 km S Golconda, Pope Co.
30. 22 May 1976, woods bordering Bay City Rd., 16.0 km S Golconda, Pope Co.
31. 22 May 1976, woods bordering Bay City Rd., 25.9 km S Golconda, Pope Co.
32. 22 May 1976, woods, 1.6 km SW Tamms, Alexander Co.
33. 20 May 1976, under logs, S jct. Thebes Rd. and Ill. Hwy. 3, Alexander Co.
34. 21 May 1976, woods bordering Ill. Hwy. 3, 0.8 km N Olive Branch, Alexander Co.

Triodopsis discoidea (Pilsbry)

Localities 15, 18, 27, and 31.

Triodopsis fraudulenta vulgata Pilsbry

Locality 26.

Triodopsis notata (DeShayes)

Localities 1, 5, 13, 18, 19, 21, 23, and 33. Baker (1939) did not list this species as a member of the Illinois polygyrid fauna. Pilsbry (1940) reported records from Hancock, Jackson, McLean, Pope, Union, Wabash and White counties. Our records are based on the anatomy of the terminal genitalia which closely resembles Pilsbry's (1940) figure 437:6. Baker (1939) may have misidentified Illinois T. notata as Mesodon appressus (Say). Whether M. appressus occurs in Illinois is not clear and further collection of anatomically verified material is needed. We found T. notata in Illinois in both upland and floodplain forests and in one case a large population (locality 19) estimated to consist of several thousand individuals was found in a junk pile at the ecotone of a woodland and grassy area bordering a railroad.

Triodopsis albolabris (Say)

35. 22 Aug. 1976, woodpile on the property of H. Morice, ca. 1.6 km SE Abraham Lincoln Memorial Park, Charleston, Coles Co.

Triodopsis multilineata (Say)

Locality 14.

Triodopsis divesta (Gould)

Locality 1. T. divesta is an Ozarkian species (Pilsbry, 1940; Solem, 1976) not previously reported from Illinois. In Illinois we have found this species only in western Monroe Co. The nearest specific record is 238 km SW at Cedar Gap, Wright Co., Mo. (Pilsbry, 1940). The Illinois population may be isolated from other populations of the species as Hubricht (1972) did not find it in St. Louis, Mo. where he has collected extensively. The Monroe Co. site is located in a physiographically Ozarkian province which extends from Jersey Co. southward to Alexander Co. adjacent to the Mississippi River. Several other organisms with Ozarkian distributions are known from Illinois only in this province, including the snail Polygyra dorfeuilliana Lea (Baker, 1939), the frog

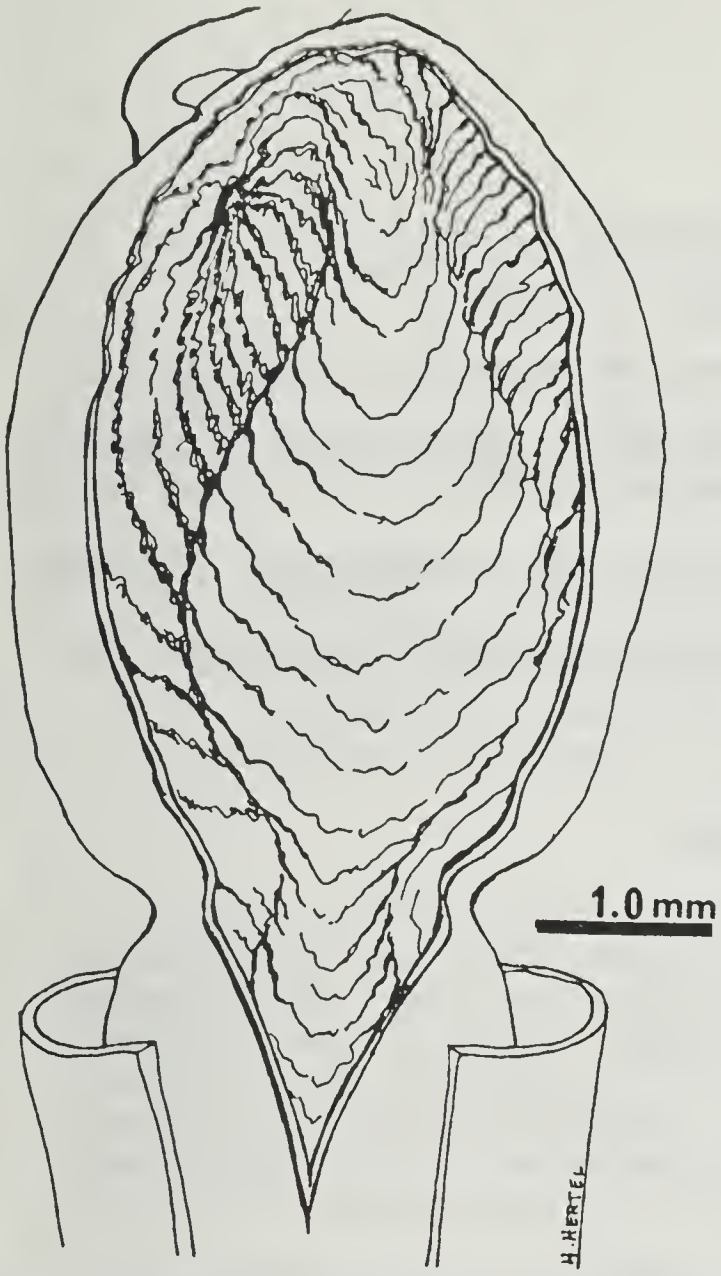

Figure 1.-Internal penial anatomy of Illinois Triodopsis divesta. Abbreviations: PP, pillaster; PS, sheath; VD, vas deferens. Drawn by H. Hertel.

Gastrophryne c. carolinensis (Holbrook), the snakes Elaphe guttata emoryi (Baird and Girard), Masticophis f. flagellum (Shaw) and Tantilla gracilis hallowelli Cope (Smith, 1961) and the composite flowers Solidago drummondii Torr. & Gray and Rudbeckia fulgida var. missouriensis (Engelm.) Cronq. (Evers, 1955). In Illinois, Masticophis f. flagellum is only known from the same area in Monroe Co. where we collected T. divesta.

Illinois T. divesta ($\bar{x}$ = 28.1 mm, range = 26.5-29.8 mm, n = 3) are larger than those reported by Solem (1976) from the Ozarks (range = 17-21 mm). Shells of Illinois T. divesta closely resemble those of T. albolabris but dissection of the penis of each of three snails shows them to be essentially vergeless (a verge is present in T. albolabris) and to closely resemble Solem's (1976) figure 4 in other details as well (Figure 1). Shell characters cited by Solem (1976) for diagnosing Ozark shells do not work well for Illinois specimens. Only the internal anatomy of the penis is reliable in differentiating specimens of T. divesta and T. albolabris. It may be that T. divesta is more widespread in Illinois than is at present known and that specimens have been misidentified as T. albolabris.

Allogona profunda (Say)

36. 28 Aug. 1976, under board in fallow field near W bank Mackinaw River at Ill. Hwy. 9, 8.0 km W Mackinaw, Tazewell Co. Pilsbry (1940) reported records from Will, Grundy, Ogle, Cook, LaSalle, Winnebago, Mercer, Rock Island and Fulton counties. The species in Illinois seems to be restricted to the northern tier of counties with the exception of populations extending down the Illinois River valley. The Tazewell Co. population is the southernmost record for the state on the east side of the Illinois River. Hubricht (1972) reported the species from St. Louis and Boone counties, Mo. Further Illinois populations may exist between Tazewell Co., Ill. and St. Louis Co., Mo. along the Illinois River and its larger tributaries.

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MANNICH CONDENSATIONS OF THIOPHENOLS. REACTION OF p-HALOTHIOPHENOLS WITH PRIMARY ALIPHATIC AMINES AND FORMALDEHYDE

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ABSTRACT - The synthesis of previously unreported 1,5-di(p-halophenyl)-1,5-dithia-3-azapentanes is reported. A study of reaction conditions necessary for preparing these compounds and the N-alkylamino methyl-p-halophenyl sulfides is discussed.

INTRODUCTION

Condensation of p-chlorobenzenethiol (ClC_6H_4SH), formaldehyde, and benzylamine has been reported (Grillot and Schaffrath, 1959(as yielding an unidentified mixture, m.p. 54-55.6° and a small quantity of N-benzylaminomethyl-p-chlorophenyl sulfide. They also reported the synthesis of N-aryl-N-methylaminomethyl aryl sulfides ($ArN(CH_3)CH_2SAr$) and three other condensations yielding 1,3,5-triaryl-1,5-dithia-3-azapentanes ($ArSCH_2NCH_2SAr$, with Ar on the N). No reference was made to the reaction of primary aliphatic amines, other than benzylamine, mentioned above with formaldehyde and thiophenols.

In previous work (Weatherbee, Sleeter and Han, 1965) in our laboratories, good yields of products from Mannich condensations of primary aliphatic amines with 2-naphthalenethiol were secured. No other references to Mannich condensations of thiophenols, formaldehyde, and primary aliphatic amines appear in the literature.

RESULTS AND DISCUSSION

In this investigation condensation of p-chlorobenzenethiol with primary aliphatic amines and formaldehyde resulted in the isolation of previously unreported 1,5-(p-chlorophenyl)-1,5-dithia-3-alkyl-3-azapentanes ($ClC_6H_4SCH_2-N(R)-CH_2SC_6H_4Cl$). Corresponding p-bromoderivatives were secured when p-bromobenzenethiol was used in lieu of the p-chlorobenzenethiol. The 3-alkyl-3-azapentane structure is assigned on the basis of elementary analysis, nmr spectra, and infrared spectra showing the absence of SH and NH stretching modes.

Condensation of benzylamine, formaldehyde, and p-chlorobenzenethiol in a 1:2:2 mole ratio, respectively, gave 1,5-di(p-chlorophenyl)-1,5-dithia-3-benzyl-3-azapentane, m.p. 53-54°. The "mixture" reported by Grillot and Schaffrath was probably this compound contaminated with N-benzylaminomethyl-p-chlorophenyl sulfide, m.p. 70-71°. The latter compound is very difficult to isolate in pure form.

The manner of mixing the reactants and the solvent used was found to have considerable effect on the yields. For the 1,5-di(p-halophenyl)-1,5-dithia-3-alkyl-3-azapentanes, addition of the amine dissolved in ethyl acetate to a solution formed by adding the formaldehyde to the thiophenol in ethyl acetate at 10-15°C gave the highest yields. Although the same products were obtained if formaldehyde were added to a solution of the amine and thiophenol, or if the thiophenol were added to solutions of the amine and formaldehyde, the yields were lower. The solvents methanol, ethanol, and dioxane normally used in our laboratories in Mannich condensations were found to give lower yields than when ethyl acetate was employed. The mole ratio of reactants used in the condensations influenced the yields. Use of an excess of amine or thiophenol drastically reduced yields. With some amines, solid material in addition to the desired 1,5-dithia-3-azapentanes was secured. The use of 100% excess of the formaldehyde resulted in the highest yields of the 1,5-dithia-3-azapentanes.

For the N-alkylaminomethyl-p-halophenyl sulfides, the 1:1:1 mole theoretical quantity of amines, formaldehyde, and thiophenol never gave the expected N-alkylaminomethyl-p-halophenyl sulfide. This probably accounts for the fact that Grillot and Schaffrath obtained a small quantity of N-benzylaminomethyl-p-chlorophenyl sulfide. Although considerable difficulty was encountered in obtaining the latter compound, a 64% yield of N-benzylaminomethyl-p-bromophenyl sulfide was secured when a 100% excess of the amine was used. In several reactions of benzylamine, formaldehyde, and p-chlorobenzenethiol, no condensation was observed and the only substance isolated was the salt of the amine and thiophenol N-benzylaminonium p-chlorophenyl sulfide.

EXPERIMENTAL

1,5-di(p-chlorophenyl)-1,5-dithia-3-benzyl-3-azapentane

To 28.8 g of p-chlorothiophenol (0.2 mole) in 100 ml of ethyl acetate was added dropwise 30 ml of 37% aqueous formaldehyde (0.4 mole) dissolved in 40 ml of ethyl acetate with stirring in an ice bath at 10-15°. To the resulting solution was added 11 ml (0.1 mole) of benzylamine, dropwise, with stirring. The solution was stirred for 5 minutes in the ice-water bath and then gradually warmed to gentle refluxing. The refluxing was continued for one hour under an atmosphere of nitrogen. Two layers formed. The solvents were removed under vacuum with a rotary evaporator, leaving an oil which solidified upon cooling. The solid was dissolved in 70 ml of warm heptane-octane mixture (70:30). Upon cooling, 41 g of solid (97% yield), m.p. 51-52°, was secured. After four recrystallizations from the heptane-octane mixture the m.p. was 53-54°. The experiment has been repeated several times giving similar results.

Analysis:

Calculated for $C_{21}H_{19}Cl_2NS_2$:	C 59.99	H 4.56	N 3.33	S 15.25
Found:	60.00	4.78	3.27	

Integration of nmr spectra of the compound dissolved in $CDCl_3$ gave 13 aryl hydrogens at 7.18 ppm, 4 CH_2-S hydrogens at 4.33 ppm, and 2-CH_2-N hydrogens at 3.81 ppm. The nmr spectra gave no D_2O exchange indicating the compound contains no easily replaceable proton, such as an NH or NH_2 group.

Infrared spectra of p-chlorothiophenol in CCl_4 gave an absorption at 256° cm^{-1} but this absorption was absent in the infrared spectra of the compound indicating the -SH hydrogen was involved in the condensation. The absence of N-H stretching vibrations in the area of 3310-3500 cm^{-1} shows that the amino hydrogens were involved in the reaction. Absorption at 633 cm^{-1} is indicative of the S-CH_2 stretching vibration.

1,5-di(p-chlorophenyl)-1,5-dithia-3-tert-octyl-3-azapentane
m.p. 69-70°, yield 52%.
Analysis:

Calculated for $C_{22}H_{29}Cl_2NS_2$:	C	59.71	H	6.61
Found:		59.80		6.70

1,5-di(p-chlorophenyl)-3-tert-butyl-1,5-dithia-3-azapentane
b.p. 170° at 3 mm, yield 44%.
Analysis:

Calculated for $C_{18}H_{21}Cl_2NS_2$:	C	55.95	H	5.48	N 3.63
Found:		55.73		5.98	3.86

1,5-di(p-bromophenyl)-3-benzyl-1,5-dithia-3-azapentane
m.p. 71-72°, yield 91%.
Analysis:

Calculated for $C_{21}H_{19}Br_2NS_2$:	C	49.52	H	3.76	N 2.75
Found:		49.75		3.82	2.72

1,5-di(p-bromophenyl)-3-tert-octyl-1,5-dithia-3-azapentane
m.p. 65-66°, yield 55%.
Analysis:

Calculated for $C_{22}H_{29}Br_2NS_2$:	C	49.72	H	5.50	N 2.64
Found:		49.93		5.43	2.52

1,5-di(p-chlorophenyl)-3-cyclohexyl-1,5-dithia-3-azapentane
b.p. 140° at 1 mm, yield 36%.
Analysis:

Calculated for $C_{20}H_{23}Cl_2NS_2$:	C	58.22	H	5.62	N 3.40
Found:		58.80		5.32	3.73

1,5-di(p-bromophenyl)-3-cyclohexyl-1,5-dithia-3-azapentane
b.p. 133° at 1 mm, yield 44%.
Analysis:

Calculated for $C_{20}H_{23}Br_2NS_2$:	C	47.91	H	4.62	N 2.79
Found:		48.53		4.40	2.56

Benzylaminomethyl p-bromophenyl sulfide

To 3.75 ml of 37% aqueous formaldehyde (0.05 mole) in 15 ml of ethyl acetate was added 11 ml (0.1 mole; 100% excess) benzylamine with stirring at 10-15°. The resulting solution was added dropwise with stirring to 9.45 g of p-bromothiophenol (0.05 mole) in 25 ml of ethyl acetate; a white solid formed during the addition. The solid dissolved as the mixture was gradually warmed to gentle refluxing over a period of 10 minutes. The solution was refluxed for one hour under nitrogen. The solvents were removed with a rotary evaporator leaving a white solid. After one recrystallization from a 70:30 heptane-octane mixture, 9.9 g of solid (64% yield), m.p. 89-94° was secured. After six recrystallizations from the heptane-octane mixture the melting point was 98°.

Analysis:

Calculated for $C_{14}H_{14}BrNS$:	C	54.55	H	4.58	N	4.54		
Found:		54.13		4.89		4.85		

N-Benzylammonium p-chlorophenyl sulfide

When p-chlorophenyl sulfide was used in lieu of the p-bromothiophenyl in the above experiment, 11.95g, (95% yield) N-Benzylammonium sulfide, m.p. 94-95°, was the only substance isolated.

Analysis:

Calculated for $C_6H_5CH_2NH_3{}^{\oplus}S^{\ominus}L_6H_4Cl$:	C	62.02	H	5.60	N	5.56	S	12.73	Cl	14.08
Found:		61.89		5.57		5.44		12.53		14.01

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DISTRIBUTION OF *CHARA* SPECIES IN ILLINOIS

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ABSTRACT: -- A total of 160 recent collections has extended the range of eight species of *Chara* in Illinois. Notes concerning the geographic distribution and county dot maps for six of these species are included. *Chara inconnexa* T. F. Allen is reported from Illinois for the first time.

Except for the taxonomic review of Stotler (1968) and the cytological studies of Williams and Tindall (1975) very little information is available concerning the Characeae of Illinois. Other works on the algae have generally ignored these plants, and at most cite only the generic names (Britton, 1944; Tiffany and Britton, 1952). In the detailed work of Stotler (1968) nine species of *Chara* are reported for the state. Most of his material comes from the southern half of Illinois. Of these, three species are known from a single collection. *Chara fibrosa* Ag. ex Bruz. (as *C. keukensis*) is reported from Wabash County; *C. kieneri* Daily is reported from Menard County; while *C. aspera* Deth. ex Willd. is reported from Cook County. The remaining species have a more general distribution, being known from scattered localities throughout Illinois. At the present time eleven species are known from Illinois. Nine of these were listed by Stotler (1968), one additional species, *Chara haitensis* Turp., was reported from two southern Illinois locations by Williams and Tindall (1975), while *C. inconnexa* T. F. Allen was found during the present study.

Some of the specimens used in the present study were collected by Conservation Biologists of the Division of Fisheries, Illinois Department of Conservation. These biologists were involved in a project that was started in 1964 (Winterringer, 1966), and resulted in the publication of a manual on the identification of aquatic plants in Illinois by Winterringer and Lopinot (1966). The remaining material was collected by the present authors during a study of aquatic communities in east-central Illinois. The specimens collected were from both natural habitats and artificial impoundments. All collections are located in the Stover Herbarium of Eastern Illinois University (EIU) with duplicate material, when available, deposited in the private herbarium of Dr. Fay Kenoyer Daily. Each species listed was found during the present study, and included for most of the species is a county map showing its distribution in Illinois. On these maps a circle represents a county in which the species had been reported previously by Stotler (1968) while a square indicates a new county record. For two of the rarer species no map is included, but the county and collecting data of the specimens are listed.

Acknowledgements: -- The authors would like to thank Dr. Fay Kenoyer Daily for her help in the identification of many of the specimens, and to Mr. Mike Conlin, Chief of the Division of Fisheries, Illinois Department of Conservation, for continuing the collecting program by the Conservation Biologists.

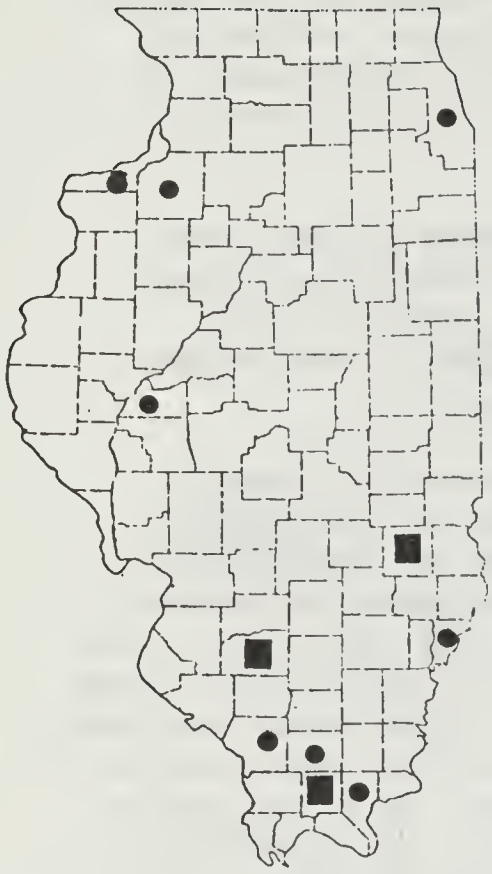
Chara braunii Gmel. -- The only totally ecorticate member of the genus Chara in Illinois. Its ecorticate condition, delicate habit, and long stipulodes in one series makes it easy to recognize. Stotler (1968) reported this species from 8 counties in Illinois, while in the present study it was found in three additional localities (Map 1).

Chara contraria A. Br. ex Kutz. --This fairly robust species commonly grows to 3 or 4 dm tall. It appears to be very similar to C. vulgaris. Grant and Proctor (1972) found no single characteristic or combination of characteristics that would provide a completely clear separation between these two species. Similar results were obtained by Wood (1967) who found that no single external morphological feature could be used for consistent separation. In studying the Illinois species Stotler (1968) also mentioned the difficulty in separating these two taxa. The following characteristics are listed by Grant and Proctor (1972) as being useful. In C. contraria the primary cortical cells of the main axis are equal to or exceed the secondary cortical in diameter, the anterior bract cells rarely exceed 3 times the length of the mature oogonia, and the oospores are black. In C. vulgaris, in contrast, the secondary cortical cells are more prominent, exceeding the diameter of the primary, the anterior bract cells are 6 to 10 times the length of the mature oogonia, and the oospores are usually brown. Stotler (1968) considered this taxon to be the most common in Illinois and recorded it for 18 counties. In the present study it is recorded for 5 additional counties (Map 2).

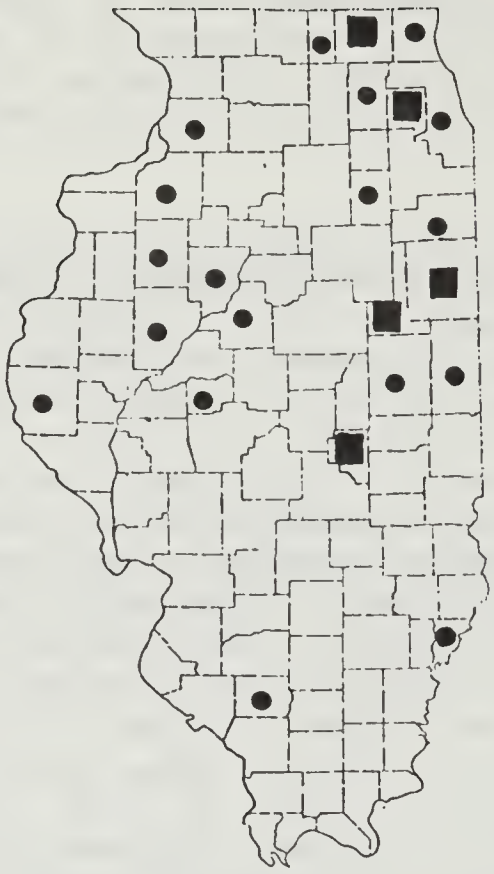
Chara fibrosa Ag. ex Bruz. --This very delicate species rarely exceeds 1 dm in length. The main axis is corticate while the branchlets are mostly ecorticate, which separates it from the other Illinois species. The taxon found during the present study is ssp. gymnopitys (A. Br.) Zanev. This extremely rare species was reported from one county (Menard) by Stotler (1968).
County record. -- CRAWFORD: Submersed in Lake Walton, 1 mile S of West York, Phillippe 2009.

Chara foliolosa Muhl. --This common species is very similar to C. zeylanica. Both have triplostichous main axis and lowest branchlet internodes that are ecorticate. The distinguishing feature of C. foliolosa is that in this species the gametangia are isolated at the branchlet nodes, with either one antheridium or one oogonium per fertile node (sejoined), while in C. zeylanica the gametangia are conjoined. Stotler (1968) referred this taxon to C. sejuncta A. Br., while that binomial is listed as a synonym by Proctor, Griffin, and Hotchkiss (1971). This taxon is probably the most common Chara in Illinois. Stotler (1968) reported it from 13 counties while it was found in 13 additional counties in the present study, occurring in many lakes and ponds in most of the counties visited (Map 3).

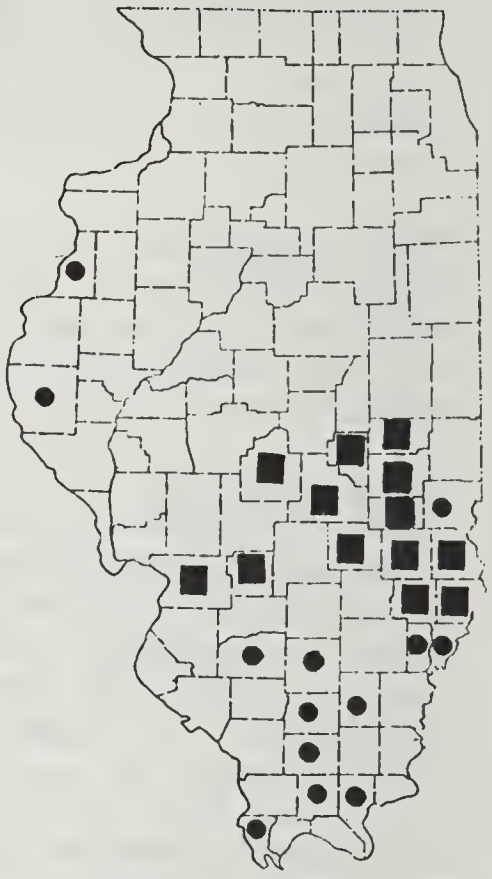
Chara globularis Thuill. --This common taxon is fairly robust, growing up to 3 dm high. The triplostichous main axis and the corticate condition of all the branchlet internodes separates it from other species commonly found



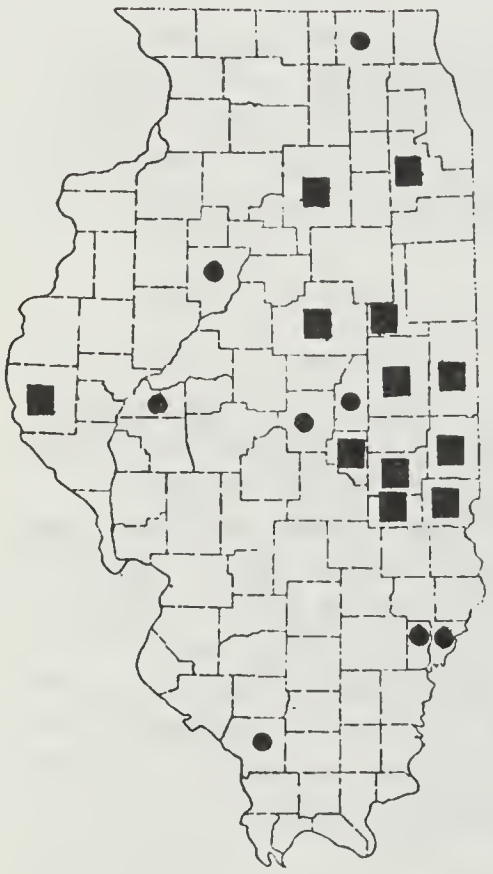
Map 1. Chara braunii



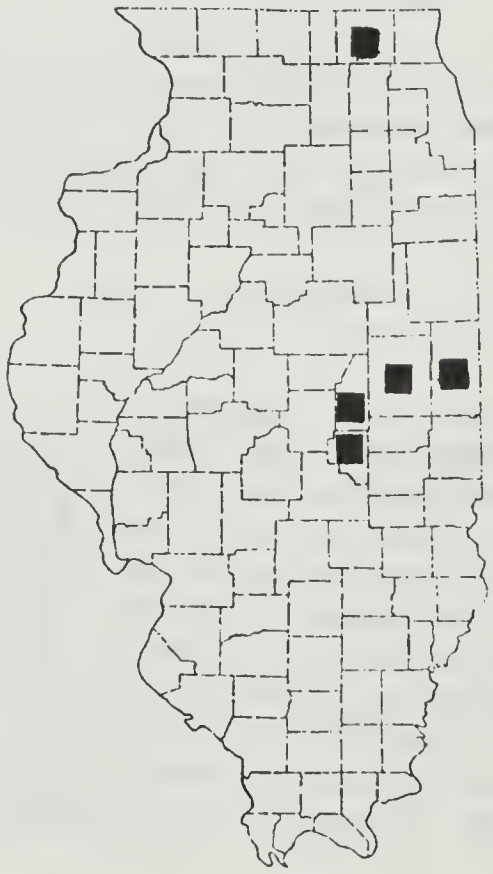
Map 2. Chara contraria



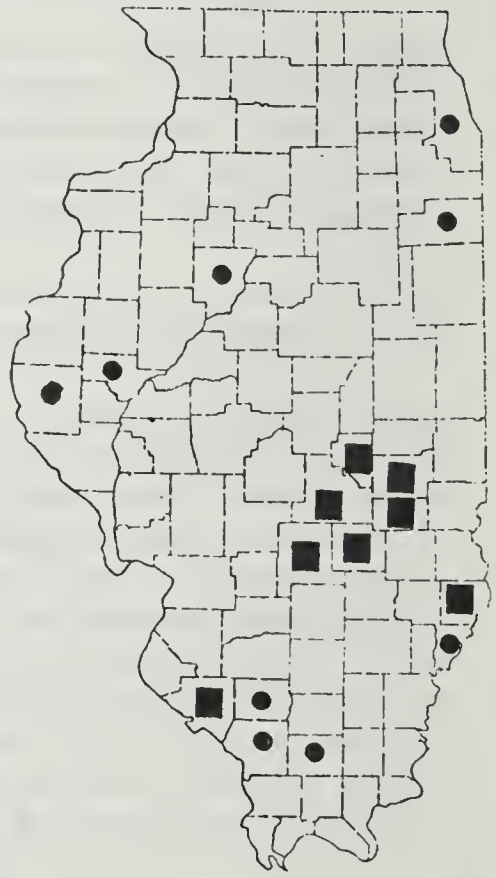
Map 3. Chara foliolosa



Map 4. Chara globularis



Map 5. Chara inconnexa



Map 6. Chara zeylanica

in Illinois. The minute spheroidal stipulodes in two series are also quite distinctive. Stotler (1968) reported it from 8 counties while it was found in 12 additional counties in the present study (Map 4).

Chara inconnexa T. F. Allen. --This taxon is very similar to C. contraria and C. vulgaris, but differs by having an incomplete and variable cortex. Wood (1967) considers it to be a variety of C. vulgaris while Stotler (1968) does not list it for Illinois. This species was found in five counties in east-central and northeastern Illinois (Map 5). Numerous specimens were found in strip mine ponds in Vermilion County.

Chara vulgaris L. --This species is fairly robust and usually heavily lime-encrusted. It is very similar to C. contraria and can only be separated on the basis of cortical cell development. Stotler (1968) reported it from three counties, all in the northern third of Illinois.
County records. -- MOULTRIE: Submersed in pond 2 miles W of Lovington, Vogel 842B. VERMILION: Submersed in small pond at Forest Glen Preserve, Ebinger 15772.

Chara zeylanica Klein ex Willd. --This taxon commonly exceeds 5 dm in height, and is the most robust Chara found in Illinois. The main axis of this species is triplostichous, and the lowest brachlet internodes are ecorticate, separating it from all other Chara species in Illinois with the exception of C. foliolosa. The conjoined gametangia of C. zeylanica are the only reliable characteristic separating these two species. Chara zeylanica, however, tends to have thick branchlets with less than 12 segments, while the branchlets of C. foliolosa usually are more delicate and have up to 16 seqments. Proctor, Griffin, and Hotchkiss (1971), in a study of the series Gymnobasalia, list C. haitensis Turpin, a species very similar to C. zeylanica, as also occurring in Illinois. This species differs from C. zeylanica in having 8 shield cells in the antheridium. During the present study it was not encountered as all of the material examined had 4 shield cells in the antheridium. Williams and Tindall (1975) recently found C. haitensis in southern Illinois. According to Stotler (1968) C. zeylanica occurs in 9 counties scattered throughout Illinois while in the present study it was found in 8 additional counties (Map 6).

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EFFECTS OF SELECTIVE AND ROW THINNINGS ON DIAMETER GROWTH IN RED PINE

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ABSTRACT

Results from a thinning study at Sinnissippi Forest in Ogle County, Illinois show that row thinning and selective thinning increase the average diameter of the residual stand. No statistically significant differences in diameter growth between row thinning and selective thinning was found in this study.

Forest stands are thinned to obtain optimum growth rates of residual trees and to improve stand quality. A variety of different thinning methods are available. Selective thinning and row thinning are the most frequently used methods.

Selective thinning or crown thinning removes trees that compete with desirable trees or crop trees for growing space. Crop trees are being favored in each of several thinnings until they constitute the final stand that will be harvested. Row thinning removes entire rows of trees mechanically. In most cases selective thinning is considered more desirable from a silvicultural standpoint, but row thinning is considered more desirable from a financial standpoint because of lower marking and harvesting costs.

An economic analysis of alternative thinning regimes has to consider both biological and financial components. This paper reports on a study of diameter growth as affected by row and selective thinnings. The final analysis would have to consider thinning and harvesting costs as well.

Reports on thinning studies in Illinois were mostly directed to other regions and species. Boggess (1959) reported on the growth of shortleaf pine thinned by crown and row method in southern Illinois.

He found that the growth of plots thinned by either method was significantly higher than that of unthinned plots, and that total basal area growth was slightly better on crown thinned plots than on row thinned plots. Burkhart and Gilmore (1967) and Gilmore and Boggess (1969) updated this report after additional thinnings. In these studies a signficant change of stand characteristics were found as compared to unthinned plots. Lorenz (1948) described thinning studies in white pine plantations conducted at Sinnissippi Forest.

METHODS

The study was conducted at Sinnissippi Forest, Ogle County, Illinois. In 1941 two plots of red pine (Pinus resinosa Ait) were established with a 6' x 6' spacing. During 1962 thinning operations were conducted on part of the area, the remainder was used as control. Thinning treatments that were applied were selective (or crown) thinning and modified row thinning. In 1970 the selectively thinned stand was thinned again.

The selective or crown thinnings removed approximately 35% of the basal area. The modified row thinning removed entire rows or every other tree in a row. Every third row was either removed completely or thinned mechanically which resulted in a comparable thinning intensity as for selective thinning.

Measurements were taken in 1960 of every third row before any treatment was applied. In 1975 the same trees that were measured previously were remeasured for computing diameter growth of the stands. As only part of the stand was measured no reference will be made to total basal area growth or volume growth, but only to diameter growth.

RESULTS AND DISCUSSION

At the 1960 measurement and average diameter did not differ significantly for the two thinning methods and the control, as shown in Table 1. The 1975 measurements showed that row thinning and selective thinning increased the average stand diameter significantly but no statistically significant difference between selective thinning and row thinning was found.

Selective Thinning. For the selective thinning the average diameter was 20.75 cm with a standard deviation of 2.445 cm which compares with an average of 16.10 cm and a standard deviation of 2.4811 for the control. The t-test resulted in a t value of 11.2156 which is significant at the 5% level, therefore it can be inferred that selective thinning increased the average stand diameter significantly.

Table 1. Tree data before and after thinnings.

	1960			1975		
	Selective	Row	Control	Selective	Row	Control
Number of observation	393	51	53	146	15	47
Average diameter	13.31	13.61	12.70	20.75	20.45	16.10
Standard deviation	2.3985	3.0277	2.8245	2.4450	1.6457	2.4811

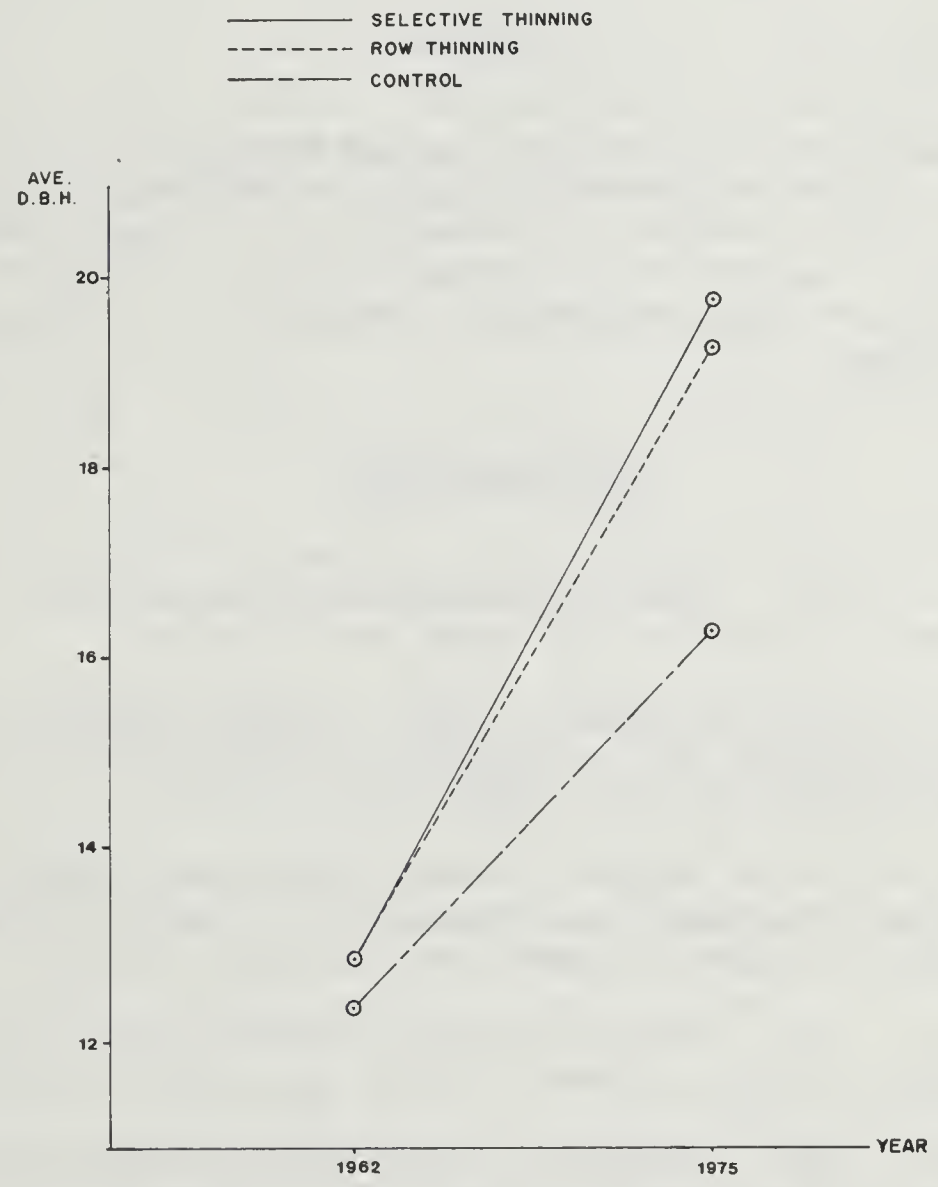

Figure 1. The Diameter Development for Selective and Row Thinnings.

Row Thinning. The row thinning resulted in an average diameter of 20.45 cm with a standard deviation of 2.4811. The comparison with the control data resulted in a t value of 7.7936 which is significant at the 5% level. Row thinning also resulted in an increase of the average stand diameter as compared to the control.

One additional hypothesis was tested to compare the two thinning methods. The comparison of row thinning and selective thinning resulted in a t value of 0.6374 which is not significant at the 5% level, i.e., it can be inferred that selective thinning and row thinning do not affect diameter growth differently. A graphical representation of the development of the average stand diameter is shown in Figure 1.

SUMMARY

Thinning studies conducted in Red Pine stands at Sinnissippi Forest showed that selective thinning and row thinning resulted in an increase in average diameter at a stand age of 34 years, thirteen years after thinning as compared with unthinned stands. No significant difference could be found between the effects of row thinning and selective thinning.

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Vol. 70, No. 1 (1977)

TREMATODE PARASITES OF THE MUSKRAT, ONDATRA ZIBETHICA ZIBETHICA, IN SOUTHERN ILLINOIS.

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ABSTRACT.-- Eighty-one muskrats, Ondatra zibethica zibethica, were collected from three southern Illinois counties, and seventy-five were infected with one or more of the following species of trematodes: Echinostoma revolutum, Quinqueserialis quinqueserialis, and Echinoparyphium recurvatum. The finding of Echinoparyphium recurvatum represents a new state record.

In recent years a number of investigations carried out in Europe and North America have indicated the muskrat, Ondatra zibethica zibethica, Linneaus 1758, to be host of a variety of species of parasitic helminths. A review of the literature includes a total of 66 species, comprising 36 trematodes, 11 cestodes, 15 nematodes and 4 acanthocephalans. Several reports summarized these helminths (Meyer and Reilly, 1950; Knight, 1951; Beckett and Gallichio, 1967).

Muskrats may serve as a resevoir host for parasites normally parasitic in domestic animals and humans. Among these are Dirofilaria immitis, Leidy 1856, (Goble, 1942; Smith, 1938), Trichinella spiralis, Owens 1835, (Beckett and Gallechio, 1967) and both the adult and larval forms of Taenia taeniaeformis, Batsch 1786, (Byrd, 1951). Muskrats also serve as a source of human food. Therefore a knowledge of parasites harbored by them would be of value to public health officials, wildlife personnel, veterinarians and parasitologists.

The only extensive study done in Illinois yielded 9 species of trematodes, 2 species of cestodes and 3 species of nematodes with an infection rate of 55.4% (Gilford, 1952). This study was limited to northern and central Illinois. Arata (1959) examined 36 muskrats

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from Perry County, Illinois and found only 2 endoparasites: one tapeworm (Monoecocestus sp.) in 1 of 36 muskrats and the trematode (Quinqueserialis quinqueserialis) in 13 of 36 animals.

Eighty-one muskrats were collected with conibear traps between August 14, 1975 and January 15, 1976 from three southern Illinois counties: Jackson, Union and Williamson. Necropsy of the entire muskrats revealed only three species of trematodes recovered from 91.2% of the male and 92.6% of the female muskrats: Echinostoma revolutum (92.6%), Quinqueserialis quinqueserialis (2.5%) and Echinoparyphium recurvatum (1.2%). The incidence of infection was 92.6% with a mean worm burden of 15.9 in the males and 13.7 in the females, with a range of 0-83 worms per muskrat. Age did not appear to be a factor, since all size classes were parasitized equally.

This report constitutes the first record of the occurrence of Echinoparyphium recurvatum in Ondatra zibethica zibethica from Illinois. Echinoparyphium recurvatum was first reported in muskrats from North America by Penner (1940) in Minnesota and later by Meyer and Reilly (1950) in Maine and lastly by Beckett and Gallechio (1967) in Ohio.

Identification of the trematodes was by means of the "Key to the trematode parasites of the muskrat" (Penner, 1940).

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A CONFIRMING REPORT OF THE PRESENCE IN SOUTHERN ILLINOIS OF BANASA SORDIDA (HEMIPTERA:PENTATOMIDAE)

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ABSTRACT. -- The presence in southern Illinois of Banasa sordida is confirmed.

Banasa sordida (Uhler) ranges from New England south to Maryland, and west to Vancouver's Island, California (Blatchley 1926), Arizona, and New Mexico (Torre-Bueno 1939). It has not been reported from Missouri (Froeschner 1941) or Indiana (Blatchley 1926). Hoffman (1971) was unable to find specimens from Virginia in collections he examined although B. sordida had been recorded from there earlier (Blatchley 1926). Recently, Furth (1974) reported it from Ohio.

Single specimens of B. sordida were collected on 30 June and on 10 July (year not given) by Hart (1919) in Grand Tower in southern Illinois. Since no further records of this species have been published for Illinois, and its distribution appears spotty in adjacent states, it would seem desirable to confirm its presence in Illinois. Given below is label information from 2 specimens of B. sordida collected in southern Illinois, and housed in the Entomology Collection, Zoology Research Museum, SIU-C.

Johnson Co., Ferne Clyffe St. Pk., 30 July 1973, 1 ♀, M. Richardson, Coll.
Pope Co., Lusk Crk., 26 Sept. 1967, 1 ♂, J. C. Downey, Coll.

LITERATURE CITED

Blatchley, W. S. 1926. Heteroptera or true bugs of eastern North America with especial reference to the faunas of Indiana and Florida. Nature Pub. Co., Indianapolis. 1116 pp.

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THE CHANGING FACE OF INORGANIC CHEMISTRY

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Until forty or fifty years ago, the beginning college course in chemistry consisted almost entirely of descriptive inorganic chemistry. Since it was the introductory course, it had to be presented at an elementary level, which meant that the most exciting and interesting parts were usually omitted. There was no mention, for example, of the existence of three isomers of $CrCl_3 \cdot 6H_2O$, of the fact that many metals play an essential role in biological processes, and only passing mention of metal-metal bonds, any reference to the latter being necessitated by the well established observation that calomel is dimeric. The existence of this substance was "explained" by pointing out that mercury is a freakish sort of metal, from which almost any behavior might be expected.

In recent years, there have been great strides in methods of analysis and in instrumentation as well as in our theories of bonding. Inorganic chemistry has benefitted from these enormously. It is true that much of the new material is not well suited for discussion in the beginning course, and it has been necessary to rearrange the college curriculum so that inorganic chemistry can be taught at the senior or graduate level.

Let us recount a few changes that have changed the nature of inorganic chemistry. There has been a tremendous growth in our knowledge and, hence, our use of metal-organic compounds, including the carbonyls, many of which are now important industrial catalysts. Advances in X-ray techniques, N.M.R., and other methods of locating atoms in solids, have made it possible to "see" what goes on in reactions, especially in the solid state. Metal-metal bonds are widely recognized now, and are the subject of intense study with regard to semiconductivity, solar energy, and catalysis. The boron hydrides, so long a stumbling block in our theories of bonding, are now fairly well understood, and their number has been greatly increased by the discovery of the carboranes and boranes containing other elements. The study of macrocycles containing multiple chelated metals is expanding rapidly, both in the area of purely synthetic compounds

and in biological materials. The study of inorganic polymers is just beginning to yield industrially useful compounds. The discovery of compounds of the rare gases has brought us new ideas of bonding and molecular structure. Molecular orbital theory, the theory of multicenter bonds and of one-electron bonds, continue to allow us to prepare new and interesting compounds and to broaden our understanding of chemistry.

These are only a few of the recent advances which have been made through the study of inorganic chemistry. There are many others, both on stage and in the wings. Inorganic chemists have never had such golden opportunities.

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THE NUTRITIONAL AND INDUSTRIAL POTENTIAL OF SOYBEANS

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In considering oilseeds as new foods for tomorrow, one of our purposes is to look at them from the point of view of the end product user and to assess characteristics that (1) are desirable or (2) limit utilization, or (3) are needed for new and expanded outlets of oilseeds. While not a purpose, an undercurrent and recurrent theme concerns how we shall achieve these desired characteristics. "Shall we attempt to breed them?" or "Shall we attempt to try to effect them by processing treatments?" In addition, there is a basic issue that needs to be resolved, if possible, with regard to nutritional potentials: "How long can Homo sapiens afford to compete with farm animals for protein supplies?" Frequently, oilseed proteins can be made available both for animal and for direct human consumption.

In surveying plant seeds worldwide as a source of protein, soybeans rank well both among major economic crops and among those of the survey. Although it is generally agreed that soybeans are raised for their meal to meet protein requirements of U.S. animal feeding economy, the byproduct oil may at times be the more valuable. Due largely to research by government and academic groups, on the one hand, and corresponding implementation of research by industry on the other, soybean oil today performs satisfactorily in margarines, shortenings, and salad oils; as a high-temperature cooking oil more research is required and is underway.

The competition of domestic soybean oil and of imported palm oil in edible markets is fundamentally a competition of photosynthetic capabilities of the two plants in their temperate and tropical environments. Whereas soybeans may produce 400 pounds of oil per acre in Illinois, palm plants produce 10 times that amount in Malaysia with an attendant lower production cost. Thus photosynthesis has a direct and immediate impact on the price the Illinois farmer receives for his soybeans.

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VASCULAR FLORA OF THE DESOTO-HALLIDAYBORO RAILROAD PRAIRIE STRIPS, JACKSON COUNTY, ILLINOIS

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ABSTRACT

A floristic survey of the vascular flora was made of the DeSoto-Hallidayboro Railroad Prairie Strips along a 3.2 mile stretch of the Illinois Central Gulf Railroad in extreme northeastern Jackson County. Representative voucher specimens of 562 specific and subspecific taxa from ninety-one families were documented and placed in the Southern Illinois University Herbarium at Carbondale (SIU). Twenty-four percent of these taxa were nonindigenous.

INTRODUCTION

A survey of the vascular plants of the DeSoto-Hallidayboro Railroad Prairie Strips in extreme northeastern Jackson County, Illinois, was conducted semimonthly from July, 1975, to October, 1977. The study area extends 3.2 miles along the Illinois Central Gulf Railroad adjacent to old U. S. Highway 51 in parts of Section 5, T8S, R1W, of the DeSoto Quadrangle, and adjacent to U. S. Highway 51 through Sections 32, 29, and 20, T7S, R1W, of the Elkville Quadrangle. Since 1968, these two disturbed mesic prairie strips have been leased to Southern Illinois University by the Illinois Central Gulf Railroad for purposes of teaching and research. This study was undertaken to present the first vascular plant list from these tracts, since these sites have been previously subjected only to incidental collecting.

Voigt and Mohlenbrock (1964) recognized the DeSoto-Hallidayboro Prairie Strips as representative of the lowland prairie situations in southern Illinois restricted to railroad rights-of-way and highways. These railroad prairie strips represent disturbed habitats which are characterized by several native prairie species, a few woody invaders, and many weedy members. The principal means of disturbance which has helped establish and maintain this prairie situation appears to be the occurrence of fires periodically along the right-of-way. These fires have allowed native prairie perennials of the Compositae, Leguminosae, Euphorbiaceae, and Gramineae, and other survivors to regenerate from underground shoots, while destroying many competitive annual species. Several typical prairie species serve as indicators of disturbance through the process of burning (Voigt and Mohlenbrock, 1964; Anderson, 1970a; Anderson and Schwegman, 1971).

For the last several years, the railroad's policy of using herbicides has exposed large tracts of bare ground through the deterioration of herbaceous cover. This practice has encouraged the growth and spread of numerous adventive and noxious weedy species. The use of herbicide sprays rather than selective burning will doubtless continue to have a detrimental effect upon the native prairie species (Anderson, 1970b).

THE PHYSICAL ENVIRONMENT

The terrain consists of flat to gently rolling and hilly upland timbered positions with a mean gradient of one to seven percent. Elevation within the study area ranges from 393 feet to 415 feet with a mean of 407 feet. The DeSoto-Hallidayboro Prairie Strips are located within the Mt. Vernon Hill Country Section of the Southern Till Plains Division of the Natural Divisions of Illinois (Schwegman, 1973). Underlying sedimentary bedrock belongs to the McLeansboro Formation of the Pennsylvanian System, and it consists of bluish clay shales and reddish or buff sandstones with a few lenticular beds of Herrin Coal (Shaw and Savage, 1912).

The soils of the DeSoto-Hallidayboro tracts are classified into five series. The upland soil series, Bluford, Hoyleton, Ava, and Wynoose, are formed in loess over glacial till. These soils are poorly drained, acid in reaction, and sixty to eighty inches in depth. The surface and subsurface layers are dark, grayish-brown silty loams, and the subsoils are mottled brown, grayish-brown, or yellowish-brown silty clay loams. The lowland soil series, Bonnie Silt Loam, is formed in acid alluvium that occures along prairie swales and seasonally wet depressions. Bonnie Soils are very poorly drained, neutral to slightly acidic in reaction, and some sixty inches deep. The surface and subsurface layers are light gray, to dark grayish-brown clayey, sandy, silty loams (Herman, Soil Conservation Service, 1976).

The climate of Jackson County is humid, continental, and subject to wide variations in temperature and precipitation. The mean annual temperature is 57.6° F. with mean temperatures of 34.9° F. during January and 79.8° F. during July. The growing season averages 186 frost-free days with the first and last killing frost occurring October 17 and April 14, respectively. The mean annual precipitation is 44.39 inches and is normally well distributed throughout the year (Denmark, Environmental Data Service, 1969).

LOWLAND MESIC PRAIRIE STRIP COMMUNITY

The various habitats, which differ in degree of disturbance, soil types, moisture-temperature relationships, and secondary successional stages, may be combined into the Lowland Mesic Prairie Strip Community. This community type is characterized by a representative assemblage of grasses and forbs with several dominant repetitious species. This plant community is briefly described according to major seasonal aspects of the flora.

Several species of woody plants are found along fencerow thickets and field edges of the right-of-way where advanced stages of secondary

succession has occurred. Major trees of canopy status include *Quercus palustris, Q. stellata, Q. imbricaria, Q. velutina, Q. marilandica,* and *Carya ovata.* The first pioneer arborescent species to invade the railroad prairie situation are *Rhus glabra, R. copallina, Sassafras albidum,* and *Diospyros virginiana.*

Common shrubs and brambles include *Rhus aromatica, Symphoricarpos orbiculatus, Ceanothus americanus, Salix humilis, Rosa carolina, Rubus flagellaris,* and *R. allegheniensis.* Arborescent species associated with prairie swale habitats are *Salix nigra, Platanus occidentalis, Populus deltoides, Sambucus canadensis, Cephalanthus occidentalis,* and *Cornus obliqua.* Woody vines intertangled in arborescent species consist mainly of *Toxicodendron radicans, Ampelopsis cordata, Parthenocissus quinquefolia, Vitis* spp., *Smilax hispida,* and *Campsis radicans.*

Several showy herbaceous species appear in the railroad prairie strips as favorable moisture and temperature conditions increase in the spring. Vernal blooming species include *Nothoscordum bivalve, Camassia scilloides, Hypoxis hirsuta, Sisyrinchium albidum, Tradescantia virginica, Comandra richardsiana, Lithospermum canescens, Oxalis violacea, Phlox pilosa, Potentilla simplex,* and *Fragaria virginiana.* Naturalized grasses commonly found are *Bromus tectorum, B. commutatus, Festuca pratensis, Poa pratensis, Dactylis glomerata,* and *Phleum pratense.*

Numerous herbaceous taxa add a colorful touch to the right-of-way during the advent of summer. Among several composites in flower are *Rudbeckia hirta, Coreopsis palmata, Parthenium integrifolium, Achillea millefolium, Erigeron* spp., and *Carduus nutans.* Attractive prairie legumes are *Amorpha canescens, Petalostemum candidum, P. purpureum, Stylosanthes biflora, Psoralea psoralioides* var. *eglandulosa, Desmanthus illinoensis, Baptisia leucantha,* and *Tephrosia virginiana.* Other conspicuous summer forbs include *Pycnanthemum tenuifolium, Monarda fistulosa, Daucus carota, Eryngium yuccifolium, Polytaenia nuttallii, Oenothera pilosella, Heuchera hirsuticaulis, Penstemon pallidus, Asclepias tuberosa* var. *interior, A. syriaca, A. verticillata, Polygala sanguinea,* and *Ruellia humilis.*

Moist lowland situations and prairie swales support a variety of the Cyperaceae, Gramineae, and Juncaceae. Common sedges include *Carex frankii, C. squarrosa, C. scoparia, C. vulpinoidea, C. crinita, Cyperus pseudovegetus, C. strigosus, C. ovularis, Eleocharis obtusa, E. tenuis, Scirpus pendulus,* and *S. cyperinus.* Grasses occupying somewhat drier habitats of the prairie swale borders are *Agrostis alba, Leersia oryzoides, Panicum lanuginosum, P. rigidulum, P. dichotomiflorum, Setaria faberi, Sorghum halepense,* and *Cinna arundinacea.* The most frequently encountered rushes are *Juncus interior, J. biflorus, J. brachycarpus, J. acuminatus,* and *J. tenuis.*

The late summer and fall aspect of these railroad prairie strips is dominated by the Compositae, Leguminosae, and Gramineae. Fall-flowering prairie composites are *Liatris pycnostachya, L. aspera, Helianthus mollis, H. grosseserratus, Silphium terebinthinaceum, S. laciniatum, Boltonia asteroides, Vernonia missurica,* and several species of *Aster, Solidago,* and *Eupatorium.* Leguminous species observed are *Strophostyles umbellata, Cassia fasciculata, C. nictitans, Desmodium illinoense, D. paniculatum,*

Crotalaria sagittalis, *Lespedeza capitata*, and *L. virginica*. A few of the other numerous late summer and fall members include *Euphorbia corollata*, *Oenothera biennis*, *Gaura biennis*, *Cuphea petiolata*, *Asclepias incarnata*, *A. hirtella*, *Mirabilis nyctaginea*, and *Verbena hastata*.

A conspicuous and attractive element of the fall prairie flora is the flowering of the native grasses. Major grasses characterizing the DeSoto-Hallidayboro Prairie Strips are *Sorghastrum nutans*, *Schizachyrium scoparium*, *Andropogon gerardii*, *A. elliottii*, *A. virginicus*, *Tridens flavus*, and in a few moist habitats, *Spartina pectinata* and *Panicum virgatum*.

The final disturbed habitat to be discussed, a wayside rest area, is situated at the northern junction of old abandoned U. S. Highway 51 and U. S. Highway 51 adjacent to the railroad right-of-way. A hybrid oak, *Quercus X bushii (Q. marilandica X Q. velutina)*, and four introduced woody taxa, *Berberis julianae*, *B. aquifolium*, *Pinus strobus*, and *P. taeda*, are found at this site. Adventive and naturalized grasses include *Poa annua*, *Cenchrus longispinus*, *Muhlenbergia schreberi*, *Lolium perenne*, *Cynodon dactylon*, and *Eleusine indica*.

In addition to the more frequently collected members of this mesic lowland prairie community, several uncommon plants are of interest. Included among these species are *Habenaria lacera*, *Rhexia virginica*, *Trillium viride*, *Sesbania exaltata*, *Ludwigia glandulosa*, *Gaura longiflora*, *Gerardia fasciculata*, *Stachys tenuifolia* var. *hispida*, *Juncus secundus*, *Sherardia arvensis*, and *Erodium circutarium*.

THE VASCULAR FLORA

Representative voucher specimens have been placed in the Herbarium of Southern Illinois University (SIU) for documentation of the following list of vascular plants. Manuals and floras used in the nonindigenous classifications and species determinations were: Mohlenbrock (1975); Steyermark (1963); Swink (1974); Fernald (1950); and Bailey (1949). Classification and nomenclature follow Mohlenbrock (1975). The plant list is divided into three sections: Pteridophyta, Gymnospermae, and Angiospermae. The listings in each division are alphabetical by family, genus, and species. An asterisk (*) before a taxon indicates a non-indigenous plant, either adventive, introduced, or naturalized, based on the definitions of Lawrence (1951, p. 279). A dagger (†) before a taxon represents a county voucher for Jackson County based on the distributional records of Mohlenbrock and Ladd (1978).

This checklist comprises a total of 91 families, 305 genera, and 562 specific and subspecific taxa. These vascular plants consist of six pteridophytes, three gymnosperms, 146 monocots, and 407 dicots. The five largest families in terms of species are: Compositae (78); Gramineae (76); Leguminosae (41); Cyperaceae (31); and Rosaceae (25). One hundred thirty-six species (24 %) are classified as adventive, introduced, or naturalized plants. Fourteen new Jackson County distributional records are documented.

PTERIDOPHYTA

EQUISETACEAE

Equisetum arvense L.

OPHIOGLOSSACEAE

Botrychium virginianum (L.) Sw.

SALVINIACEAE

Azolla mexicana Presl

POLYPODIACEAE

Asplenium platyneuron (L.) Oakes
Onoclea sensibilis L.
Pteridium aquilinum (L.) Kuhn. var. *latiusculum* (Desv.) Underw.

GYMNOSPERMAE

CUPRESSACEAE

Juniperus virginiana L.

PINACEAE

**Pinus strobus* L.
**Pinus taeda* L.

ANGIOSPERMAE

ACANTHACEAE

Ruellia humilis Nutt.

ACERACEAE

Acer negundo L.
Acer saccharinum L.

AIZOACEAE

**Mollugo verticillata* L.

ALISMATACEAE

Alisma subcordatum Raf.
Sagittaria calycina Engelm.

AMARANTHACEAE

**Amaranthus albus* L.
**Amaranthus hybridus* L.
**Amaranthus tamariscinus* Nutt.
**Froelichia gracilis* (Hook.) Moq.

ANACARDIACEAE

Rhus aromatica Ait.
Rhus copallina L.
Rhus glabra L.
Toxicodendron radicans (L.) Kuntze

ARACEAE

Arisaema dracontium (L.) Schott.

APOCYNACEAE

Amsonia tabernaemontana Walt.
Apocynum cannabinum L.

AQUIFOLIACEAE

Ilex decidua Walt.

ASCLEPIADACEAE

Asclepias hirtella (Pennell) Woodson
Asclepias incarnata L.
Asclepias syriaca L.
Asclepias tuberosa L. var. *interior* (Woodson) Shinners
Asclepias verticillata L.
Cynanchum laeve (Michx.) Pers.

BALSAMINACEAE

Impatiens biflora Walt.

BERBERIDACEAE

**Berberis aquifolium* Pursh
**Berberis julianae* Schneid.

Podophyllum peltatum L.

BETULACEAE

Betula nigra L.
Corylus americana Walt.

BIGNONIACEAE

Campsis radicans (L.) Seem.

BORAGINACEAE

**Lithospermum arvense* L.
Lithospermum canescens (Michx.) Lehm.
Mysotis virginica (L.) BSP.

CALLITRICHACEAE

Callitriche terrestris Raf.

CAMPANULACEAE

Lobelia cardinalis L.
Lobelia inflata L.
Lobelia spicata Lam.
Specularia biflora (R. & P.) Fisch. & Meyer
Specularia perfoliata (L.) DC.

CAPRIFOLIACEAE

**Lonicera japonica* Thunb.
Sambucus canadensis L.
Triosteum angustifolium L.
Viburnum recognitum Fern.
Viburnum rufidulum Raf.

CARYOPHYLLACEAE

Cerastium nutans Raf.
**Cerastium vulgatum* L.
**Dianthus armeria* L.
**Holosteum umbellatum* L.
**Saponaria officinalis* L.
Silene antirrhina L.
Silene stellata (L.) Ait.
**Stellaria media* (L.) Cyrillo

CELASTRACEAE

Celastrus scandens L.

CERATOPHYLLACEAE

Ceratophyllum demersum L.

CHENOPODIACEAE

**Chenopodium album* L.
**Chenopodium dessicatum* A. Nels. var. *leptophylloides* (Murr.) Wahl.
Chenopodium missouriense Aellen
**Chenopodium polyspermum* L.
Chenopodium standleyanum Aellen
**Salsola kali* L. var. *tenuifolia* Tausch.

CISTACEAE

Lechea minor L.
Lechea tenuifolia Michx.

COMMELINACEAE

**Commelina communis* L.
Tradescantia ohiensis Raf.
Tradescantia virginiana L.

COMPOSITAE

**Achillea millefolium* L.
Ambrosia artemisiifolia L.
Ambrosia bidentata Michx.
Ambrosia trifida L.
Antennaria neglecta Greene
**Anthemis cotula* L.
Aster ericoides L.
Aster novae-angliae L.
Aster patens Ait.
Aster pilosus Willd.
Aster praealtus Poir.
Bidens aristosa L.
Bidens bipinnata L.
Bidens connata Muhl.
Boltonia asteroides (L.) L'Her.
Calcalia atriplicifolia L.
**Carduus nutans* L.
**Centaurea maculosa* Lam.
**Chrysanthemum leucanthemum* L.
**Cichorium intybus* L.
Cirsium discolor (Muhl.) Spreng.
**Cirsium vulgare* (Savi) Tenore
Coreopsis palmata Nutt.
Coreopsis tripteris Michx.
Eclipta alba (L.) Hassk.

Erectites hieracifolia (L.) Raf.
Erigeron annuus (L.) Pers.
Erigeron canadensis L.
Erigeron philadelphicus L.
Erigeron strigosus Muhl.
Eupatorium altissimum L.
Eupatorium fistulosum Barrett
Eupatorium perfoliatum L.
Eupatorium rugosum L.
Eupatorium serotinum Michx.
Gnaphalium obtusifolium L.
Gnaphalium purpureum L.
Helenium autumnale L.
Helenium flexuosum Raf.
**Helianthus annuus* L.
Helianthus divaricatus L.
Helianthus grosseserratus Martens
Helianthus mollis Lam.
Helianthus petiolaris Nutt.
Helianthus tuberosus L.
Helianthus tuberosus L. var. *subcanescens* Gray
†**Iva xanthifolia* Nutt.
**Krigia dandelion* (L.) Nutt.
Lactuca canadensis L.
**Lactuca serriola* L.
Liatris aspera Michx.
Liatris pycnostachya Michx.
Liatris squarrosa (L.) Michx.
Parthenium integrifolium L.
Pyrrhopappus carolinianus (Walt.) DC.
Ratibida pinnata (Vent.) Barnh.
Rudbeckia hirta L.
Rudbeckia triloba L.
Senecio glabellus Poir.
Silphium integrifolium Michx.
Silphium laciniatum L.
Silphium terebinthinaceum Jacq.
Solidago canadensis L.
Solidago gigantea Ait.
Solidago graminifolia (L.) Salisb.
Solidago juncea Ait.
Solidago missouriensis Nutt.
Solidago nemoralis Ait.
Solidago rigida L.
**Sonchus asper* (L.) Hill
**Taraxacum officinale* Weber
†**Tragopogon dubius* Scop.
† *Verbesina alternifolia* (L.) Britt.
Verbesina helianthoides Michx.
Vernonia baldwinii Torr.
Vernonia gigantea (Walt.) Trel.
Verononia missurica Raf.
**Xanthium strumarium* L.

CONVOLVULACEAE

Calystegia sepium (L.) R. Br.
**Convolvulus arvensis* L.
Cuscuta campestris Yuncker
Cuscuta compacta Juss.
Cuscuta gronovii Willd.
**Ipomoea hederacea* (L.) Jacq.
Ipomoea lacunosa L.
Ipomoea pandurata (L.) G. F. Meyer
**Ipomoea purpurea* (L.) Roth

CORNACEAE

Cornus drummondii C. A. Meyer
Cornus florida L.
Cornus obliqua Raf.
Cornus racemosa Lam.

CRASSULACEAE

†**Sedum telephium* L.

CRUCIFERAE

**Barbarea vulgaris* R. Br. var. *arcuata* (Opiz) Fries
†**Brassica juncea* (L.) Coss.
**Brassica kaber* (DC.) L. Wheeler var. *pinnatifida* (Stokes) Wheeler
**Camelina microcarpa* Andrz.
**Capsella bursa-pastoris* (L.) Medic.
Cardamine parviflora L. var. *arenicola* (Britt.) Schultz
Dentaria laciniata Muhl.
Draba brachycarpa Nutt.
**Draba verna* L.
**Erysimum repandum* L.
**Hesperis matronalis* L.
**Lepidium campestre* (L.) R. Br.
Lepidium virginicum L.
Rorippa sessiliflora (Nutt.) Hitchc.
**Sisymbrium altissimum* L.
**Thlaspi arvense* L.

CYPERACEAE

Carex annectens Bickn.
Carex blanda Dewey
Carex bushii Mackenz.

Carex cephalophora Muhl.
† *Carex conjuncta* Booth
Carex crinata Lam.
Carex cristatella Britt.
Carex frankii Kunth
Carex hirsutella Mackenz.
Carex lanuginosa Michx.
Carex lurida Wahlenb.
Carex meadii Dewey
Carex muhlenbergii Schk.
Carex scoparia Schk.
Carex shortiana Dewey
Carex squarrosa L.
Carex tenera Dewey
Carex tribuloides Wahlenb.
Carex vulpinoidea Michx.
Cyperus erythrorhizos Muhl.
Cyperus esculentus L.
Cyperus ovularis (Michx.) Torr.
Cyperus pseudovegetus Steud.
Cyperus strigosus L.
Eleocharis acicularis (L.) R. & S.
Eleocharis macrostachya Britt.
Eleocharis obtusa (Willd.) Schultes
Eleocharis tenuis (Willd.) Schultes var. *verrucosa* Svenson
Scirpus atrovirens Willd.
Scirpus cyperinus (L.) Kunth
Scirpus pendulus Muhl.

DIOSCOREACEAE

Dioscorea villosa L.

EBENACEAE

Diospyros virginiana L.

ELAEAGNACEAE

†**Elaeagnus umbellata* Thunb.

EUPHORBIACEAE

Acalypha gracilens Gray
Acalypha virginica L.
Chamaesyce humistrata (Engelm.) Small
Chamaesyce maculata (L.) Small
**Chamaesyce supina* (Raf.) Moldenke
Croton capitatus Michx.
**Croton glandulosus* L. var. *septentrionalis* Muell-Arg.
Croton monanthogynus Michx.
Crotonopsis elliptica Willd.
Euphorbia corollata L.
**Euphorbia cyparissias* L.
**Poinsettia dentata* (Michx.) Kl. & Garcke

FAGACEAE

Quercus bicolor Willd.
† *Quercus X bushii* Sarg.
Quercus imbricaria Michx.
Quercus marilandica Muenchh.
Quercus stellata Wang.
Quercus velutina Lam.

GENTIANACEAE

Sabatia angularis (L.) Pursh

GERANIACEAE

**Erodium circutarium* (L.) L'Her.
Geranium carolinianum L.
Geranium maculatum L.

GRAMINEAE

**Agrostis alba* L.
Agrostis hyemalis (Walt.) BSP.
Agrostis scabra Willd.
Alopecurus carolinianus Walt.
Andropogon elliottii Chapm.
Andropogon gerardii Vitman
Andropogon virginicus L.
Aristida longespica Poir.
Aristida oligantha Michx.
Aristida ramossissima Engelm.
**Avena sativa* L.
**Bromus commutatus* Schrad.
**Bromus inermis* Leyss.
Bromus pubescens Muhl.
**Bromus secalinus* L.
**Bromus tectorum* L.
Cenchrus longispinus (Hack.) Fern.
Chasmanthium latifolium (Michx.) H. O. Yates
Cinna arundinacea L.
**Cynodon dactylon* (L.) Pers.
**Dactylis glomerata* L.
Danthonia spicata (L.) Beauv.
**Digitaria ischaemum* (Schreb.) Muhl.
**Digitaria sanguinalis* (L.) Scop.

Echinochloa crusgalli (L.) Beauv.
**Eleusine indica* (L.) Gaertn.
Elymus canadensis L.
Elymus villosus Muhl.
Elymus virginicus L.
**Eragrostis cilianensis* (All.) Mosher
Eragrostis pectinacea (Michx.) Nees
Eragrostis spectabilis (Pursh) Steud.
**Festuca arundinacea* Schreb.
**Festuca pratensis* Huds.
Glyceria striata (Lam.) Hitchc.
**Hordeum jubatum* L.
Hordeum pusillum Nutt.
Leersia oryzoides (L.) Swartz
**Lolium perenne* L.
Muhlenbergia frondosa (Poir.) Fern.
Muhlenbergia schreberi J. F. Gmel.
Panicum anceps Michx.
Panicum capillare L.
Panicum clandestinum L.
Panicum dichotomum L.
Panicum dichotomiflorum Michx.
Panicum lanuginosum Ell. var. *implicatum* (Scribn.) Fern.
Panicum lanuginosum Ell. var. *lindheimeri* (Nash) Fern.
Panicum oligosanthes Schult. var. *scribnerianum* (Nash) Fern.
† *Panicum praecocius* Hitchc. & Chase
Panicum rigidulum Bosc
Panicum virgatum L.
Paspalum floridanum Michx.
Paspalum laeve Michx.
Paspalum pubiflorum Rupr. var. *glabrum* Vasey
**Phleum pratense* L.
**Poa annua* L.
**Poa compressa* L.
**Poa pratensis* L.
Schizachyrium scoparium (Michx.) Nash
**Secale cereale* L.
**Setaria faberi* Herrm.
**Setaria lutescens* (Weigel.) Hubb.
**Setaria viridis* (L.) Beauv.
Sorghastrum nutans (L.) Nash
**Sorghum bicolor* (L.) Moench.
**Sorghum halepense* (L.) Pers.
Spartina pectinata Lind.
Sphenopholis nitida (Biehler) Scribn.
Sporobolis asper (Michx.) Kunth
Tridens flavus (L.) Hitchc.
Tripsacum dactyloides L.
**Triticum aestivum* L.
**Triticum cylindricum* (Host) Ces.
Vulpia octoflora (Walt.) Rydb.
**Zea mays* L.

HYPERICACEAE

Hypericum drummondii (Grev. & Hook.) Torr. & Gray
Hypericum gentianoides (L.) BSP.
Hypericum mutilum L.
Hypericum punctatum Lam.
Hypericum spathulatum (Spach) Steud.
Hypericum sphaerocarpum Michx.

IRIDACEAE

**Iris germanica* L.
Iris shrevei Small
Sisyrinchium albidum Raf.

JUGLANDACEAE

Carya glabra (Mill.) Sweet
Carya ovata (Mill.) K. Koch
Carya tomentosa (Poir.) Nutt.
Juglans nigra L.

JUNCACEAE

Juncus acuminatus Michx.
Juncus biflorus Ell.
Juncus brachycarpus Engelm
Juncus dudleyi Wieg.
Juncus effusus L. var. *solutus* Fern. & Wieg.
Juncus interior Wieg.
† *Juncus secundus* Beauv.
Juncus tenuis Willd.

LABIATAE

Hedeoma hispida Pursh
**Lamium amplexicaule* L.
**Lamium purpureum* L.
Lycopus americanus Muhl.
Monarda fistulosa L.
Physostegia virginiana (L.) Benth.
Prunella vulgaris L. var. *lanceolata* (Bart.) Fern.
Pycnanthemum tenuifolium Schrad.

Scutellaria parvula Michx. var. *leonardii* (Epling) Fern.
Stachys tenuifolia Willd.
† *Stachys tenuifolia* Willd. var. *hispida* (Pursh) Fern.
Teucrium canadense L. var. *virginicum* (L.) Eat.

LAURACEAE

Sassafras albidum (Nutt.) Nees

LEGUMINOSAE

Amorpha canescens Pursh
Apios americana Medic.
Baptisia leucantha Torr. & Gray
Cassia fasciculata Michx.
Cassia nictitans L.
Cercis canadensis L.
**Coronilla varia* L.
Crotalaria sagittalis L.
Desmanthus illinoensis (Michx.) MacM.
Desmodium ciliare (Muhl.) DC.
Desmodium cuspidatum (Muhl.) Loud.
Desmodium illinoense Gray
Desmodium laevigatum (Nutt.) DC.
Desmodium paniculatum (L.) DC.
Desmodium sessilifolium (Torr.) Torr. & Gray
Gleditsia tricanthos L.
**Glycine max* (L.) Merr.
Lespedeza capitata Michx.
**Lespedeza cuneata* (Dum.-Cours.) G. Don.
Lespedeza procumbens Michx.
**Lespedeza stipulacea* Maxim.
**Lespedeza striata* (Thunb.) H. & A.
Lespedeza violacea (L.) Pers.
Lespedeza virginica (L.) Britt.
**Medicago lupulina* L.
**Medicago sativa* L.
**Melilotus alba* Desr.
**Melilotus officinalis* (L.) Lam.
Petalostemum candidum (Willd.) Michx.
Petalostemum purpureum (Vent.) Rydb.
Psoralea psoralioides (Walt.) Cory var. *eglandulosa* (Ell.) Freeman
Robinia pseudoacacia L.
† *Sesbania exaltata* (Raf.) Cory
Strophstyles umbellata (Muhl.) Britt.
Stylosanthes biflora (L.) BSP.
Tephrosia virginiana (L.) Pers.
**Trifolium campestre* Schreb.
**Trifolium hybridum* L.
**Trifolium pratense* L.
**Trifolium repens* L.
**Vicia dasycarpa* Ten.

LEMNACEAE

Lemna minor L.
Spirodela polyrhiza (L.) Schleiden

LENTIBULARIACEAE

Utricularia gibba L.

LILIACEAE

Allium canadense L.
**Allium vineale* L.
**Asparagus officinalis* L.
Camassia scilloides (Raf.) Cory
Erythronium albidum Nutt.
**Hemerocallis fulva* L.
Hypoxis hirsuta (L.) Coville
Lilium michiganense Farw.
**Narcissus pseudonarcissus* L.
**Ornithogalum umbellatum* L.
Polianthes virginica (L.) Shinners
Polygonatum commutatum (Schultes) A. Dietr.
Trillium viride Beck
**Yucca filamentosa* L. var. *smalliana* (Fern.) Ahles

LYTHRACEAE

Ammannia coccinea Rottb.
Cuphea petiolata (L.) Koehne
Lythrum alatum Pursh
Rotala ramosior (L.) Koehne

MALVACEAE

**Abutilon theophrastii* Medic.
Hibiscus lasiocarpus Cav.
**Sida spinosa* L.

MELASTOMACEAE

Rhexia virginica L.

MORACEAE

Humulus lupulus L.
**Morus alba* L.
Morus rubra L.

NELUMBONACEAE

Nelumbo lutea (Willd.) Pers.

NYCTAGINACEAE

Mirabilis nyctaginea (Michx.) MacM.

OLEACEAE

Fraxinus pennsylvanica Marsh. var. *subintegerrima* (Vahl.) Fern.

ONAGRACEAE

Gaura biennis L.
† *Gaura longiflora* Spach.
Jussiaea repens L.
Ludwigia alternifolia L.
† *Ludwigia glandulosa* Walt.
Ludwigia palustris (L.) Ell. var. *americana* (DC.) Fern. & Grisc.
Oenothera biennis L.
Oenothera laciniata Hill
Oenothera pilosella Raf.

ORCHIDACEAE

Habenaria lacera (Michx.) Loud.

OXALIDACEAE

**Oxalis corniculata* L.
Oxalis dillenii Jacq.
Oxalis violacea L.

PASSIFLORACEAE

Passiflora lutea L. var. *glabriflora* Fern.

PHYTOLACCACEAE

Phytolacca americana L.

PLANTAGINACEAE

Plantago aristata Michx.
**Plantago lanceolata* L.
Plantago rugelii Dcne.
Plantago virginica L.

PLATANACEAE

Platanus occidentalis L.

POLEMONIACEAE

Phlox glaberrima L. var. *interior* Wherry
Phlox pilosa L.

POLYGALACEAE

Polygala sanguinea L.
Polygala verticillata L. var. *ambigua* (Nutt.) Wood

POLYGONACEAE

**Polygonum aviculare* L.
**Polygonum convolvulus* L.
Polygonum erectum L.
Polygonum hydropiper L.
Polygonum hydropiperoides Michx.
**Polygonum lapathifolium* L.
Polygonum pensylvanicum L. var. *laevigatum* Fern.
**Polygonum persicaria* L.
Polygonum prolificum (Small) Robins
Polygonum punctatum Ell.
Polygonum scandens L.
Polygonum setaceum Baldw. var. *interjectum* Fern.
**Rumex acetosella* L.
**Rumex crispus* L.
Rumex verticillatus L.

PORTULACACEAE

Claytonia virginica L.

PRIMULACEAE

Lysimachia lanceolata Walt.

RANUNCULACEAE

Ranunculus abortivus L.
Ranunculus hispidus Michx.
Ranunculus micranthus Nutt.
**Ranunculus sardous* Crantz
Thalictrum dioicum L.

RHAMNACEAE

Ceanothus americanus L.

ROSACEAE

Agrimonia parviflora Ait.
Crataegus calpodendron (Ehrh.) Medic.
Crataegus crus-galli L.
Crataegus pruinosa (Wendl.) K. Koch
Fragaria virginiana Duchesne
Geum canadense Jacq.
Geum vernum (Raf.) Torr. & Gray
Malus ioensis (Wood) Britt.
**Malus pumila* Mill.
**Potentilla recta* L.
Potentilla simplex Michx.
Prunus americana Marsh.
Prunus americana Marsh. var. Sudw.
Prunus angustifolia Marsh.
Prunus munsoniana Wight & Hedrick
Prunus serotina Ehrh.
**Rosa canina* L.
Rosa carolina L.
**Rosa damascena* Mill.
**Rosa multiflora* Thunb.
Rosa setigera Michx.
Rubus allegheniensis Porter
Rubus argutus Link.
Rubus flagellaris Willd.
**Spiraea prunifolia* Sieb. & Zucc.

RUBIACEAE

Cephalanthus occidentalis L.
Diodia teres Walt.
Galium aparine L.
Galium obtusum Bigel
Galium pilosum Ait.
Houstonia purpurea L. var. *calycosa* Gray
**Sherardia arvensis* L.

SALICACEAE

Populus deltoides Marsh.
Salix humilis Marsh.
Salix nigra Marsh.

SANTALACEAE

Comandra richardsiana Fern.

SAXIFRAGACEAE

Heuchera hirsuticaulis (Wheelock) Rydb.
Penthorum sedoides L.

SCROPHULARIACEAE

**Chaenorrhinum minus* (L.) Lange
Gerardia fasciculata Ell.
Lindernia dubia (L.) Pennell
Mimulus alatus Ait.
Penstemon digitalis Nutt.
Penstemon pallidus Small
Penstemon tubaeflorus Nutt.
Scrophularia marilandica L.
**Verbascum blattaria* L.
**Verbascum thapsus* L.
**Veronica arvensis* L.
Veronica peregrina L.
Veronicastrum virginicum (L.) Farw.

SMILICACEAE

Smilax bona-nox L.
Smilax glauca Walt.
Smilax hispida Muhl.
Smilax pulverulenta Michx.

SOLANACEAE

**Datura stramonium* L. var. *tatula* (L.) Torr.
Physalis heterophylla Nees var. *ambigua* (Gray) Rydb.
Physalis pruinosa L.
Physalis subglabrata Mack. & Bush
Solanum americanum Mill.
Solanum carolinense L.

TYPHACEAE

Typha angustifolia L.
Typha latifolia L.

ULMACEAE

Celtis occidentalis L.
Ulmus americana L.
Ulmus rubra L.

UMBELLIFERAE

Chaerophyllum procumbens (L.) Crantz
Chaerophyllum tainturieri Hook.
Cicuta maculata L.
**Conium maculatum* L.
**Daucus carota* L.
Eryngium yuccifolium Michx.
Polytaenia nuttallii DC.
Thaspium trifoliatum (L.) Gray
Thaspium trifoliatum (L.) Gray var. *flavum* Blake
**Torilis japonica* (Houtt.) DC.

URTICACEAE

Boehmeria cylindrica (L.) Sm.
Parietaria pensylvanica Muhl.
Pilea pumila (L.) Gray

VALERIANACEAE

Valerianella radiata (L.) Dufr.

VERBENACEAE

Lippia lanceolata Michx.
Verbena canadensis (L.) Britt.
Verbena hastata L.
Verbena simplex Lehm.
Verbena urticifolia L.

VIOLACEAE

Viola pratincola Greene
**Viola rafinesquii* Greene
Viola sagittata Ait.

VITACEAE

Ampelopsis cordata Michx.
Parthenocissus quinquefolia (L.) Planch.
Vitis aestivalis Michx.
Vitis cinerea Engelm.
Vitis palmata Vahl.
Vitis vulpina L.

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A GENERAL SOLUTION OF WHITTAKER'S TYPE FOR THE BIHARMONIC EQUATION IN THREE VARIABLES*

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ABSTRACT. The author first gives a short derivation of E. T. Whittaker's general solution of Laplace's equation $\nabla^2 u = 0$, *viz.*, $u = \int_{-\pi}^{\pi} f(Z,\alpha)\,d\alpha$, where $Z = x + iy\cos\alpha + iz\sin\alpha$ and f is an essentially arbitrary function. Whittaker's theorem is then generalized in two directions. Firstly, it is shown that Whittaker's result may be extended to Laplace's equation in n independent variables ($n \geq 3$). Secondly, it is shown that the given formula represents a solution of the biharmonic equation if Z is extended to have values in a certain linear associative algebra. Furthermore, the author shows how the latter solution may itself be extended to the general polyharmonic equation in $n \geq 3$ variables.

INTRODUCTION

By the term *general solution* of a partial differential equation, let us understand an expression which satisfies the equation and which depends upon at least one (sufficiently differentiable) arbitrary function. For example, let $z = x + iy$, and let $f(z)$ be an arbitrary holomorphic function on a domain $\mathfrak{D}$ of the complex plane. Then it is well-known that such a general solution of Laplace's equation on $\mathfrak{D}$, *viz.*,

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0 \qquad (1)$$

*This paper is based, in part, on a paper of the same title read at the joint meeting of the Illinois State and Missouri Academies of Science, and the Missouri chapter of the Mathematical Association of America, held at University of Missouri at St. Louis, April 29, 1977.

is given by

$$u = f(z) \tag{2}$$

For Laplace's equation in three independent variables,

$$\nabla^2 u = \nabla \cdot \nabla u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = 0 \tag{3}$$

there also exists a (perhaps less well-known) general solution due to Whittaker (Whittaker and Watson (1920)). We shall give here a brief derivation of Whittaker's solution. By analogy with (2), let us seek a solution of (3) in the form

$$u = f(Z),\ Z = Ax + By + Cz \tag{4}$$

where A, B, C are constant quantities (i.e., independent of x, y, z) to be determined. Let f be any $C^{(2)}$-function on a suitable domain. Then, by the chain rule, we have

$$\nabla^2 u = f''(Z)\ (A^2 + B^2 + C^2).$$

It follows that $\nabla^2 u = 0$ for every function f of the class provided that (A, B, C) are the coordinates of a point on the "surface", i.e., on the algebraic variety whose equation is

$$A^2 + B^2 + C^2 = 0. \tag{5}$$

Since (5) has only trivial real solutions, such a variety is necessarily complex. A simple complex parameterization of (5) is given by $A = 1$, $B = i\cos\alpha$, $C = i\sin\alpha$, whence it follows that every $C^{(2)}$-function $f(Z)$ of the complex quantity

$$Z = x + iy\cos\alpha + iz\sin\alpha \tag{6}$$

is a solution of (3). More generally, if $f(r,s)$ is a $C^{(2)}$-function of its first argument (at least), then $f(Z,\alpha)$ is also a solution. Indeed, we see that in general the integral

$$u = u(x,y,z) = \int_{-\pi}^{\pi} f(Z,\alpha)\,d\alpha \tag{7}$$

is a solution of (3) for all sufficiently smooth functions, f. *This is Whittaker's general solution of* (3). In particular, when (7) has the form

$$u = \int_{-\pi}^{\pi} f(Z)\ e^{-im\alpha}\ d\alpha \tag{8}$$

then the right-hand side of (8) is a solution of (3) for every integer m.

The Whittaker formulas (7) and/or (8) may be made the

basis of systematic exposition of certain important collections of harmonic functions in three variables. For example--returning briefly to the plane case--it is well-known that there are exactly two linearly independent homogeneous polynomial solutions of (1), of given degree $n \geq 1$, viz., $\mathrm{Re}(z^n)$ and $\mathrm{Im}(z^n)$. To obtain such solutions of (3), let us set in (7) (by analogy with the plane case) $f(Z) = Z^n$, and write Z from (6) in spherical coordinates (ρ, θ, ϕ), where

$$\begin{aligned} x &= \rho \cos \theta \\ y &= \rho \sin \theta \cos \phi \\ z &= \rho \sin \theta \sin \phi \end{aligned}$$

Then it may be shown that

$$\begin{aligned} \int_{-\pi}^{\pi} Z^n e^{-im\alpha} d\alpha &= \rho^n \int_{-\pi}^{\pi} [\cos \theta + i \sin \theta \cos(\alpha - \phi)]^n e^{-im\alpha} d\alpha \\ &= \rho^n e^{-im\phi} \int_{-\pi}^{\pi} [\cos \theta + i \sin \theta \cos \psi]^n e^{-im\psi} d\psi \\ &= \frac{2\pi i^m n!}{(m+n)!} \rho^n P_n^m(\cos \theta) e^{-im\phi}, \quad m=0,1,\ldots,n. \end{aligned} \tag{9}$$

Now the real and imaginary parts of (9) (ignoring the constant factor $2\pi i^m n!/(m + n)!$, which is unimportant for this discussion) are given by (respectively)

$$\rho^n P_n^m(\cos \theta) \cos m\phi, \quad \rho^n P_n^m(\cos \theta) \sin m\phi \tag{10}$$

$$(m = 0, 1, \ldots, n).$$

But expressions (10) represent, for given $n \geq 1$, $2n + 1$ linearly independent and homogeneous polynomial solutions of (3), or--as they are usually known--the solid spherical harmonics of degree n. (It is well-known that there are at most $2n + 1$ linearly independent such harmonics.)

It may be shown in a similar way that if one sets $f(Z) = e^{pZ}$ (where $p = \text{const.} > 0$) in (8), with Z expressed in cylindrical coordinates r, ϕ, x then (8) is proportional to the cylindrical harmonic,

$$e^{px} J_m(pr) e^{im\phi},$$

$$(m = 0, \pm 1, \pm 2, \ldots);$$

and if $f(Z) = 1/Z$, then u is proportional to $1/\rho = (x^2 + y^2 + z^2)^{-1/2}$, the potential at the origin of unit point charge at (x, y, z).

EXTENSION OF WHITTAKER'S SOLUTION TO n VARIABLES

We shall show in this section how Whittaker's general solution of Laplace's equation in three variables may be extended to n independent variables, i.e., to solutions $u = u(x_1, x_2, \ldots, x_n)$ of

$$\frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} + \ldots + \frac{\partial^2 u}{\partial x_n^2} = 0 \qquad (11)$$

In the notation $x_1, x_2, x_3, \ldots$ for the independent variables, let us write $Z_2 = x_1 + ix_2$ for the usual complex variable, then $Z_3 = x_1 + ix_2 \cos \alpha_1 + ix_3 \sin \alpha_1$ in place of Z in (6). Now we observe that Z_3 may be regarded as being derived from Z_2 by the transformation:

$$x_2 \to x_2 \cos \alpha_1 + x_3 \sin \alpha_1.$$

If we apply the corresponding transformation to Z_3, viz.,

$$x_3 \to x_3 \cos \alpha_2 + x_4 \sin \alpha_2$$

we obtain

$$Z_4 = x_1 + ix_2 \cos \alpha_1 + ix_3 \sin \alpha_1 \cos \alpha_2 + ix_4 \sin \alpha_1 \sin \alpha_2$$

and furthermore

$$\nabla^2 f(Z_4) = f''(Z_4)(1 - \cos^2\alpha_1 - \sin^2\alpha_1 \cos^2\alpha_2 - \sin^2\alpha_1 \sin^2\alpha_2)$$
$$= 0.$$

Proceeding in the same way, the transformation $x_4 \to x_4 \cos \alpha_3 + x_5 \sin \alpha_3$ carries Z_4 to Z_5, whence $f(Z_5)$ satisfies (11) with $n = 5$, and the sequence is clear. It seems unnecessary to supply the remaining details of the induction. Indeed, we suppose this theorem to be reasonably well-known, although we are unaware of an explicit published account.

THE BIHARMONIC EQUATION

When the Laplace operator is applied k times to an unknown function u of class $C^{(2k)}$, and the result made to vanish, the resulting equation is called polyharmonic. In particular,

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)^2 u = \frac{\partial^4 u}{\partial x^4} + 2\,\frac{\partial^4 u}{\partial x^2 \partial y^2} + \frac{\partial^4 u}{\partial y^4} = 0 \qquad (12)$$

is the biharmonic equation in the plane. Similarly, the six-term equation represented by

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)^2 u = 0 \qquad (13)$$

is the biharmonic equation in three variables. Both (12) and (13) are important in the theory of elasticity (cf., e.g., in the well-known treatises of A. E. H. Love (1927), p. 135; I. S. Sokolnikoff (1946), p. 79 and S. Timoshenko and J. N. Goodier (1951), p. 27, 29, 183). These equations play a role in the theory of elasticity somewhat the same as Laplace's equation does in theory of the potential.

L. Sobrero (1934 a, b, c, d) was evidently the first to conceive of a generalized complex function-theory for biharmonic functions on plane domains, i.e., for solutions of (12). Proceeding (with Sobrero) by analogy to the classical case--(1) and (2) above--let us seek solutions of (12) of the form $u = f(z)$. Now, however, we set $z = x + jy$, j being a new quantity (independent of x and y) to be determined. Again using the chain rule, (12) yields, for any $C^{(4)}$-function f,

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)^2 u = f^{(4)}(Z)(1 + j^2)^2. \qquad (14)$$

Certainly (14) is satisfied if $j = i$: but this solution represents nothing new, since any harmonic function is trivially biharmonic. To satisfy (14) non-trivially, it follows that j is obliged to lie in some other algebra than the complex field, i.e., an algebra in which $1 + j^2 \neq 0$, but

$$(1 + j^2)^2 = j^4 + 2j^2 + 1 = 0 \qquad (15)$$

(the quantity $1 + j^2$ thus being nilpotent of order 2). Hence we introduce, with Sobrero, the linear associative and commutative algebra $\mathcal{B}$ of all elements of the form $a + jb + j^2c + j^3d$, with (from (15)) $j^4 = -1 - 2j^2$, and in which a, b, c, d are real-valued. Thus $\mathcal{B}$ is a four-dimensional algebra, being spanned by the basis elements $\{1, j, j^2, j^3\}$, but $z = x + jy$ lies in the two-dimensional linear subspace of $\mathcal{B}$ spanned by 1 and j. Then, for example,

$$z^2 = x^2 + j2xy + j^2y^2,$$
$$z^3 = x^3 + j3x^2y + j^23xy^2 + j^3y^3,$$
$$z^4 = x^4 + j4x^3y + j^26x^2y^2 + j^34xy^3 + j^4y^4;$$

but $j^4 = -1 - 2j^2$, whence the last-written power becomes

$$z^4 = x^4 - y^4 + j4x^3y + j^2(6x^2y^2 - 2y^4) + j^3 4xy^3$$

and it may be verified directly that the individual component functions $x^4 - y^4$, $4x^3y$, etc. of z^4 are solutions of (12) (as are, indeed, the component functions of z^m for every positive integral m).

From such simple and intuitively appealing beginnings, Sobrero proceeded to the rigorous development of a substantial theory of functions on the algebra $\mathcal{B}$, defining (along classical lines) "holomorphe Funktionen der hyperkomplexen Variablen" $z = x + jy$. It is not our purpose here to recapitulate Sobrero's theory, however, but to show how his general solution of (12) via the algebra $\mathcal{B}$ is also related to the general solution of (13) in much the same way that the general solutions (2) and (7) are connected. (For Sobrero's theory we remark that his Hamburg monograph is a gem. Concerning linear associative algebras or--as they are sometimes still called--hypercomplex number systems generally, we must refer to such standard works as MacDuffee (1948), Dickson (1914) and Albert (1939).)

GENERAL SOLUTION OF THE BIHARMONIC EQUATION IN THREE VARIABLES

If we seek a solution of (13) in the form (4), then one obtains

$$\nabla^2\nabla^2 u = f^{(4)}(Z)(A^2 + B^2 + C^2)^2 = 0$$

which is satisfied non-trivially by every $C^{(4)}$-function f provided $(A^2 + B^2 + C^2)^2 = 0$ but $A^2 + B^2 + C^2 \neq 0$. Hence we set $A = 1$, $B = j \cos \alpha$, $C = j \sin \alpha$, where j is the basis element from the algebra $\mathcal{B}$, described above. Then $Z = x + jy \cos \alpha + jz \sin \alpha$ and $f(Z)$ satisfies (13) as also does

$$\int_{-\pi}^{\pi} f(Z, \alpha)\, d\alpha \tag{16}$$

and, in particular,

$$u = \int_{-\pi}^{\pi} f(Z) e^{-im\alpha} d\alpha. \tag{17}$$

To indicate the possibilities afforded by general solutions (16) and/or (17), the latter will now be applied to direct calculation of the spherical biharmonics, the homogeneous polynomial solutions of (13). Setting $f(Z) = Z^n$ in (17),

$$u = \int_{-\pi}^{\pi} (x + jy \cos \alpha + jz \sin \alpha)^n e^{im\alpha} d\alpha. \tag{18}$$

In the reduction of (18), it is helpful to exploit another property of the algebra $\mathcal{B}$ (attributed by Sobrero (1934a) to Levi-Civita): it may be shown that $\left(\frac{3j + j^3}{2}\right)^2 = -1$, i.e., we may set $i = \frac{1}{2}(3j + j^3)$. With this representation of i, and setting $\omega = 1 + j^2$, it is readily shown that

$$a + jb + j^2c + j^3d$$
$$= a - c + i(b - d) + \omega\left[c + i\,\frac{3d - b}{2}\right] \tag{19}$$

so that any element of $\mathcal{B}$ may be written essentially as a linear combination of two complex quantities with, moreover, the coefficient ω satisfying $\omega^2 = 0$. Applying the identity (19) to Z in (18), we obtain

$$Z = Z_1 + \omega Z_2 \tag{20}$$

where

$$Z_1 = x + iy\cos\alpha + iz\sin\alpha, \quad Z_2 = -\frac{i}{2}(y\cos\alpha + z\sin\alpha).$$

We may now see how (19) simplifies the computational algebra of $\mathcal{B}$-valued quantities: from (20), we have $Z^2 = Z_1^2 + 2\omega Z_1 Z_2$, $Z^3 = Z_1^3 + 3\omega Z_1^2 Z_2$, ... and, by induction

$$Z^n = Z_1^n + n\omega Z_1^{n-1} Z_2 \tag{21}$$
$$(n = 0, 1, 2, \ldots).$$

Introducing spherical coordinates (as in (8) and (9)), we have

$$Z_1 = \rho[\cos\theta + i\sin\theta\cos(\phi - \alpha)], \quad Z_2 = -\frac{i}{2}\rho\sin\theta\cos(\phi - \alpha)$$

whence (18) becomes

$$\int_{-\pi}^{\pi} Z^n e^{-im\alpha} d\alpha = \rho^n \int_{-\pi}^{\pi} [\cos\theta + i\sin\theta\cos(\alpha - \phi)]^n e^{-im\alpha} d\alpha$$
$$-\frac{1}{2}\omega n\rho^n \sin\theta \int_{-\pi}^{\pi} [\cos\theta + i\sin\theta\cos(\alpha - \phi)]^{n-1} \cos(\alpha - \phi) e^{-im\alpha} d\alpha$$
$$= \rho^n e^{-im\alpha} \int_{-\pi}^{\pi} [\cos\theta + i\sin\theta\cos\psi]^n e^{-im\psi} d\psi$$
$$-\frac{i}{4}\omega n\rho^n e^{-im\phi}\sin\theta \left[\int_{-\pi}^{\pi} \cos\theta + i\sin\theta\cos\psi\right]^{n-1} e^{-i(m-1)\psi} d\psi \tag{22}$$
$$+ \int_{-\pi}^{\pi} [\cos\theta + i\sin\theta\cos\psi]^{n-1} e^{-i(m+1)\psi} d\psi$$

Comparing (9) and (22), we see that the latter may now be

evaluated, virtually by inspection, to give

$$u = \frac{2\pi i^m n!}{(m+n)!}\rho^n P_n^m(\cos\theta)e^{-im\phi}$$
$$- \frac{1}{4}\omega n\rho^n e^{-im\phi}\sin\phi\left[\frac{2\pi i^{m-1}(n-1)!}{(m+n-2)!}P_{n-1}^{m-1}(\cos\theta)\right.$$
$$\left. + \frac{2\pi i^{m+1}(n-1)!}{(m+n)!}P_{n-1}^{m+1}(\cos\theta)\right]. \tag{23}$$

Let us notice that the first term on the right in (23), since it coincides with (9), is a spherical harmonic. It follows that the additional terms on the right, which are due to the introduction of the algebra $\mathcal{B}$, represent proper biharmonic functions; and we want to observe, in particular, that once (18) and (20) are known, (23) then follows with essentially no more difficulty than the classical spherical harmonics from the integral (9).

Some further simplification of (23) yields the expression

$$u = \frac{2\pi i^m n!}{(m+n)!}\rho^n e^{-im\phi}\left[P_n^m(\cos\theta)\right.$$
$$\left. + \frac{1}{4}\omega(P_{n-1}^{m+1}(\cos\theta)\sin\theta - (m+n)(m+n-1)P_{n-1}^{m-1}(\cos\theta)\sin\theta)\right]. \tag{24}$$

To obtain real-valued spherical biharmonics--similar to (10)--we remark first that the constant multiplier $2\pi i^m n!/(m+n)!$ may again be discarded; then we write $\omega = 1 + j^2$ in (24) and also take care to observe the form which is assumed in $\mathcal{B}$ by Euler's identity, viz.,

$$e^{-im\phi} = \cos m\phi - \frac{3j + j^3}{2}\sin m\phi. \tag{25}$$

Upon multiplying (25) by the square-bracketed factor in (24) and collecting components along the $\mathcal{B}$-basis, there finally results

$$\rho^n[P_n^m(\cos\theta)+\frac{1}{4}(P_{n-1}^{m+1}(\cos\theta)\sin\theta$$
$$-(m+n)(m+n-1)P_{n-1}^{m-1}(\cos\theta)\sin\theta)]\cos m\phi$$
$$-j\cdot\frac{1}{4}\rho^n[6P_n^m(\cos\theta)+P_{n-1}^{m+1}(\cos\theta)\sin\theta$$
$$-(m+n)(m+n-1)P_{n-1}^{m-1}(\cos\theta)\sin\theta]\sin m\phi \qquad (26)$$
$$+j^2\cdot\frac{1}{4}\rho^n(P_{n-1}^{m+1}(\cos\theta)\sin\theta$$
$$-(m+n)(m+n-1)P_{n-1}^{m-1}(\cos\theta)\sin\theta)\cos m\phi$$
$$-j^3\cdot\frac{1}{4}\rho^n[2P_n^m(\cos\theta)+P_{n-1}^{m+1}(\cos\theta)\sin\theta$$
$$-(m+n)(m+n-1)P_{n-1}^{m-1}(\cos\theta)\sin\theta]\sin m\phi$$

in which each component represents a set of spherical biharmonic functions.

THE BIHARMONIC EQUATION IN n VARIABLES

We may regard $Z_3 = x + jy\cos\alpha + jz\sin\alpha$ $= x_1 + jx_2\cos\alpha_1 + jx_3\sin\alpha_1$ as being obtained from $z = x_1 + jx_2$ by the transformation $x_2 \to x_2\cos\alpha_1 + x_3\sin\alpha_1$. And if we apply to x_3 in Z_3 the transformation $x_3 \to x_3\cos\alpha_2 + x_4\sin\alpha_2$, then there is induced on Z_3 the transformation $Z_3 \to Z_4$, where

$$Z_4 = x_1 + jx_2\cos\alpha_1 + jx_3\sin\alpha_1\cos\alpha_2 + jx_4\sin\alpha_1\sin\alpha_2$$

and it is easily shown that $u = f(Z_4, \alpha_1, \alpha_2)$ satisfies

$$\left(\frac{\partial^2}{\partial x_1^2}+\frac{\partial^2}{\partial x_2^2}+\frac{\partial^2}{\partial x_3^2}+\frac{\partial^2}{\partial x_4^2}\right)^2 u = 0 \qquad (27)$$

as does

$$u = \int_{-\pi}^{\pi}\int_{-\pi}^{\pi} f(Z_4, \alpha_1, \alpha_2)\,d\alpha_1\,d\alpha_2$$

and it is clear, in principle, how this same scheme leads to the general solution of the biharmonic equation in $n \geq 3$ independent variables.

THE GENERAL POLYHARMONIC EQUATION

In the cases considered above, we have shown how to obtain a solution of Whittaker's type for certain equations other than Laplace's by extending from a known two-dimensional case. We shall now show, without undue attention to

details, how the same reasoning may be applied to the general polyharmonic equation of degree k, viz.,

$$\left(\frac{\partial^2}{\partial x_1^2} + \frac{\partial^2}{\partial x_2^2} + \ldots + \frac{\partial^2}{\partial x_n^2}\right)^k u = 0.$$

It will suffice here to consider k = 3, and begin with the corresponding polyharmonic equation in the plane,

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial x^2}\right)^3 u = 0. \tag{28}$$

Then, applying (28) to u = f(z), z = x + jy, gives

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial x^2}\right)^2 u = f^{(6)}(z)(1 + j^2)^3 = 0.$$

Hence, introduce now the commutative and associative algebra $\mathfrak{A}$, of dimension 6, spanned by 1, j, ..., j^5 satisfying

$$j^6 = -1 - 3j^2 - 3j^4$$

(since $(1 + j^2)^3 = 0$, but $(1 + j^2)^2 \neq 0$). It follows that the six components of every regular function of x + jy are solutions of (28). But then if we set $Z = x + jy\cos\alpha + jz\sin\alpha$, $j \in \mathfrak{A}$, then every $C^{(6)}$-function $f(Z, \alpha)$ satisfies

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)^3 u = 0 \tag{29}$$

as does also the corresponding Whittaker integral,

$$u = \int_{-\pi}^{\pi} f(Z, \alpha)d\alpha. \tag{30}$$

Of course, it does not follow that one may obtain from (30) the spherical polyharmonics (for example) with the same facility by which we were led to (22) (and thence to the expressions (26)), since we do not yet possess for the algebra $\mathfrak{A}$ any identity similar to (19).

CONCLUDING REMARKS AND SOME COMMENTS ON GENERAL SOLUTIONS IN PARTIAL DIFFERENTIAL EQUATIONS

In our analysis above, we have given a short derivation of Whittaker's general solution of Laplace's equation in three variables. It was then shown that essentially the same method carries over to Laplace's equation in $n \geq 3$ variables. In all such cases, the solution is given by an

integral of an arbitrary function of an argument Z lying on a certain complex manifold. Proceeding then to the biharmonic equation in three variables, it was shown that our method continues to hold provided, however, that Z takes values on a suitable hypercomplex manifold (or, as we sometimes prefer to say, in a linear associative algebra). An application was made to determination of the spherical biharmonics of positive integral degree. Finally, the method used to obtain a general solution of Whittaker's type for the biharmonic equation was found to be also applicable in principle to the general polyharmonic equation in n variables.

It is clear that the results given above belong (in part) to the theory of general solutions of partial differential equations in the sense stated at the beginning: i.e., our concern has been to obtain representations of solutions in terms of essentially arbitrary functions. However, it is well-known that it may not be feasible to adapt such a general solution to the needs of a boundary and/or initial value problem associated with a partial differential equation. What, then, is the proper place of such solutions in a general theory? To our mind, it is scarcely possible to improve upon the discussion of this question given by N. I. Muskhelishvili (1953), and therefore we conclude by quoting him in extenso (op. cit., p. 422):

> ...general representations of the solutions of partial differential equations by means of "arbitrary" functions acquired exaggerated importance at the outset of the development of mathematical physics...But it soon became clear that the determination of [such] a "general solution" by no means exhausted a problem and that for the solutions of the corresponding boundary problems such general solutions were often next to useless.
>
> This fact caused the usual reaction in such cases and led to other extreme points of view which have been dominant until quite recent times, i.e., that no benefit whatsoever may be derived from "general solutions."
>
> However, in actual fact, this is not so. The general solutions, if they can be found and if they are used efficiently, are often extraordinarily useful, particularly in practical problems. In a number of such cases they permit the construction of a complete theory of a given problem in a manner which is simpler and more thorough than would have been possible by other, hitherto known methods; the theory of plane elasticity may serve here as an example.

> In contrast to this, the hitherto known, general solutions of the equations of the three-dimensional theory of elasticity do not permit the construction of a complete general theory; however, they have been found to be useful for the solution of a number of a number of problems of a special character and have served as means for the solution of several general problems.

Indeed, Whittaker's general solution of Laplace's equation is employed, in the spirit just described, in the treatise of Whittaker and Watson (op. cit., Ch. XVIII passim).

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THE FAMILY LYTHRACEAE IN ILLINOIS

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ABSTRACT

The family Lythraceae in Illinois is composed of six genera and eight species. Synonymy, descriptions, and ecology of each species is given. A key to the taxa is provided.

INTRODUCTION

The descriptive data as well as some of the geographical distribution information was obtained from specimens in the herbaria of Southern Illinois University and the Illinois State Museum.

The writer wishes to express his gratitude to Dr. R.H. Mohlenbrock whose generous assistance in matters concerning the style of arrangement, bibliographic materal, and taxonomic problems encountered has been very valuable, and to Dr. L. Koelling for the use of the facilities at the Illinois State Museum Herbarium.

LYTHRACEAE--Loosestrife Family

Herbs, shrubs, or trees, with opposite, or sometimes alternate or whorled, entire, simple leaves, most without stipules. Branches normally 4-sided.

Flowers perfect, regular or slightly irregular, generally 4- to 7-merous, axillary or terminal, solitary, cymose, racemose or spicate, sometimes dimorphic or trimorphic, the style and the filaments being reciprocally longer and shorter on different plants. Calyx globose to tubular, often nerved, bearing the 4-14 stamens and the 4-7, frequently caducous petals on its inner throat, the latter inserted above the stamens. Stamens usually 2X the number of the petals. Petals sometimes lacking. Ovary superior, completely or incompletely 2-6 celled; style 1, capitate or rarely 2-lobed. Fruit a capsule, often 1-locular; seeds numerous, without endosperm.

The family is composed of approximately 22 genera and 500 species, most abundant in the tropics, especially the American tropics.

KEY TO THE GENERA OF LYTHRACEAE IN ILLINOIS

1. Plants more or less shrubby; leaves, or some of them, whorled----------1. *DECODON*
1. Plants herbaceous; leaves opposite or the uppermost alternate (or rarely whorled in *Lythrum salicaria*)----------2.
   2. Plants vicid-pubescent; flowers slightly zygomorphic----2. *CUPHEA*
   2. Plants glabrous or variously pubescent, but not vicid; flowers actinomorphic----------3.
3. Calyx with 5, 6, or 7 lobes or teeth, the tube cylindrical----------3. *LYTHRUM*
3. Calyx with 4 lobes or teeth, the tube hemispherical----------4.
   4. Plants usually in water; petals none; leaves up to 3.5 mm broad----------4. *PEPLIS*
   4. Plants usually not in water; petals 4; leaves mostly over 3.5 mm broad----------5.
5. Flowers usually one per leaf axil; leaves tapering to a short petiole or a sessile or subsessile base; capsule dehiscing septicidally----------5. *ROTALA*
5. Flowers usually in cymes in the leaf axils; leaves auriculate, truncate or rounded at the base; capsule dehiscing irregularly----------6. *AMMANNIA*

1. *DECODON* J.F. Gmel. Syst. Veg. 2:677. 1791. Swamp Loosestrife, Water Willow.

Herb or slightly shrubby plant with opposite or whorled leaves. Flowers trimorphic, the styles of three lengths; calyx globose with 5-7 lobes at the apex, alternating with as many horn-like appendages in the sinuses; petals 5, showy; stamens 10, of two lengths; capsule globose, loculicidal.

This genus is distinguished from other genera of the family in Illinois by its suffrutescent growth form, its much larger size, and its ecological preference for aquatic habitats.

It is a monotypic genus.

1. *DECODON VERTICILLATUS* (L.) Ell. Bot. S.C. and Ga. 1:544. 1821.
   Lythrum verticillatum L. Sp. Pl. 446. 1753.
   Nessaea verticillata (L.) HBK. Nov. Gen. 6:191. 1823.
   Decodon verticillatus var. *leavigatus* Torr. & Gray, Fl. N. Am. 1:483. 1840
   Decodon verticillatus var. *pubescens* Torr. & Gray, Fl. N. Am. 1:483. 1840

Herbaceous perennial, somewhat woody at the base. Stem 4-angled, elongate, slender, usually arched or recurved, glabrous to villous, up to 3 M tall. Leaves in whorls of 3 or 4 or occasionally opposite, simple, lanceolate to linear-lanceolate, acute at the apex and the base. glabrous to villous on the midvein below, lighter on the lower surface, up to 18 cm long, up to 6 cm broad; petiole up to 1.3 cm long, glabrous to villous; stipules absent.

Flowers in dense, showy clusters in the upper axils, trimorphic on glabrous to villous pedicels up to 1.5 cm long. Calyx hemispheric to broadly campanulate, up to 6.5 mm long, glabrous to occasionally sparsely pilose, divided above into 5-7 lobes with 5-7 longer, linear appendages between the lobes. Petals 5, free, narrowly obovate-spatulate, violet, glabrous, up to 15 mm long. Stamens 10, 5 long-exerted, 5 shorter, included or nearly so, attached to the calyx tube. Pistil 1; style of 3 lengths; stigma capitate; ovary superior. Fruit a subglobose capsule with numerous small seeds.

COMMON NAMES: Swamp Loosestrife, Water Willow.
HABITAT: Swamps and shallow water.
RANGE: Maine to Minnesota, south to Kansas and Florida.
ILLINOIS DISTRIBUTION: Scattered through the state.

Although quite distinct, this species could be confused with *Lythrum salicaria*. The latter species shares with *D. verticillatus* a tristylous condition and, rarely, whorled leaves. However, *D. verticillatus* is usually partly woody and has an inflorescense of flowers in clusters in the upper leaf axils. Also, this species commonly exhibits a spongy thickening of its submerged parts, and roots at the tips of its long, slender, arching branches. The inflorescense of *L. salicaria*, a totally herbaceous species, is a dense terminal spike or raceme.

Some authors divide this species into a pubescent form, var. *verticillatus*, and a glabrous form, var. *laevigatus*. Both varieties occur in Illinois, but because they are often found growing in the same colonies, and because they intergrade, I do not believe they qualify for varietal status.

Patterson (1876) and Schneck (1876) called this species *Nessaea verticillata* (L.) HBK., but this name is synonymous with *Decodon verticillatus* (L.) Ell.

Specimens examined--LAKE: Cedar Lake, Fuller 13256 (ISM). MASON: W. of Saidora, Winterringer 11373 (ISM). SALINE: Cottonwood Pond, Bailey & Swayne 8750 (SIU). UNION: Pine Hills, Mohlenbrock 11255 (ISM).

2. *CUPHEA* P. Br. Hist. Jamiac. 216. 1756. Waxweed.

Herbs or shrubs with opposite leaves. Flowers zygomorphic, solitary or racemose, stalked; calyx tubular, strongly ribbed, gibbous at the base, with 6 teeth at the apex and usually as many appendages in the sinuses; petals 6, unequal; stamens usually 11 or 12, unequal; capsule ovoid or oblongoid, few seeded, opening from one side.

The genus is easily separated from the other genera of the Lythraceae in Illinois by its terete stem, zygomorphic flowers, gibbous calyx, bilobed stigma, and vicid-villous pubescence.

An American genus of over 200 species.

Only the following species occurs in Illinois;

1. *CUPHEA PETIOLATA* (L.) Koehne, Bot. Jahrb. 2:173. 1882.
Lythrum petiolatum L. Sp. Pl. 446. 1753.
Cuphea viscosissima Jacq. Hort. Vind. 2:83pl. 177. 1772.
Parsonia petiolata L. Rusby, Mem. Torrey Club 5:231. 1894.

Herbaceous perennial with fibrous or tap roots. Stem terete, usually freely branched, viscid-villous, erect, up to 45 cm tall. Leaves opposite, simple, lanceolate to ovate-lanceolate, acute at the apex, obtuse to rarely tapering at the base, lightly puberulent, heavier on the veins, darker on the upper surface, up to 5 cm long, up to 1.5 cm wide; petioles viscid-villous, up to 1.3 cm long; stipules setose.

Flowers solitary to racemose in the axils; peduncles up to 2.2 mm long, viscid-villous; pedicels up to 2 mm long, viscid-villous. Calyx tubular to urceolate, gibbous, 12-ribbed, up to 1 cm long, viscid-strigose along the ribs, divided above into 6 lobes with 6 small appendages between the lobes. Petals 6, free, unequal, spatulate, violet, glabrous, up to 3.5 mm long. Stamens (7-) 11, unequal, usually included, attached to the calyx tube. Pistil 1; style 1, slender, included to slightly exerted, with a 2-lobed, capitate stigma; ovary superior. Fruit an oblong capsule with a few large flattened seeds.

COMMON NAME: Waxweed.
HABITAT: Dry, open soil.
RANGE: Rhode Island to Iowa and Kansas, south to Louisiana and Georgia.
ILLINOIS DISTRIBUTION: Common in the southern half of the state, becoming less common northward; apparently absent in the northern one-fifth of the state, except for Cook and Grundy counties.

Up to 1900, this species had been known as *C. viscosissima* Jacq., but the binomial *C. petiolata* clearly has priority.

Specimens examined.--HARDIN: Near Shetlerville, Ozment s.n. (SIU). JACKSON: Near Hurst, McCree 1164 (SIU). JASPER: N. of Yale, Winterringer 20287 (ISM). JEFFERSON: Near Mt. Vernon, Wright s.n. (SIU). MACON: E. of Spitler Woods State Park, Shildneck C-5299 (ISM). PERRY: S. of Swanwick, Koelling 5041 (ISM). POPE: Lusk Creek, Hopkins s.n. (SIU). RANDOLPH: Rock Castle Creek, Wilson 1554 (SIU). RICHLAND: N. of Olney, Winterringer 20156 (ISM). SALINE: Old Stone Face, Keser 347 (SIU). UNION: N. of Wolf Lake, Mohlenbrock 11273 (SIU). WILLIAMSON: Near Bush, McCree 570 (SIU). WOODFORD: S. of Spring Bay, Jones 14293 (SIU).

3. *LYTHRUM* L. Sp. Pl. 446. 1753. Loosestrife.

Herbs or shrubs, often virgately branched, with opposite, alternate or whorled leaves. Flowers often dimorphic or trimorphic; calyx cylindrical to campanulate with 4-6 (-7) lobes alternating with as many appendages between the lobes; petals 4-6; stamens as many as or 2x as many as the petals; capsule subcylindrical, septicidal.

The combination of a tubular calyx, a 6-merous condition, and di- and trimorphic flowers distinguishes this genus from all others in the Illinois Lythraceae.

Approximately 30 species, mostly in the north temperate zone; a few found in the southern and western states.

The following represent the only Illinois species:

KEY TO THE SPECIES OF *LYTHRUM* IN ILLINOIS.

1. Flowers solitary, axillary; uppermost leaves mostly alternate----------1. *L. alatum*
1. Flowers in terminal spikes or racemes; uppermost leaves opposite or whorled----------2. *L. salicaria*

1. *LYTHRUM ALATUM* Pursh, Fl. Am. Sept. 334. 1814.

Herbaceous perennial with taproots. Stems 4-angled, usually slightly winged, glabrous, erect, up to 90 cm tall. Leaves opposite or partly alternate, simple, linear-oblong to ovate-lanceolate, acute at the apex, rounded, truncate or cordate at the base, glabrous, lighter on the lower surface, up to 4 cm long, up to 1.1 cm broad, sessile; stipules absent.

Flowers dimorphic, solitary to occasionally cymose in the upper leaf axils, sessile or rarely on glabrous pedicels up to 2 mm long. Calyx tubular, narrowly 12-winged, up to 7 mm long, glabrous, divided above into 5-7 lobes with 5-7 appendages between the lobes. Petals 5-7, free, obovate, purple, glabrous, up to 6 mm long, usually shorter than the calyx. Stamens 6, exerted or included, attached to the calyx tube. Pistil 1; style 1, exerted or included; stigma capitate; ovary superior. Fruit a tubular to tubular-urceolate capsule with numerous small seeds.

COMMON NAME: Loosestrife.
HABITAT: Moist or wet soil, prairies, swamps, and meadows.
RANGE: Massachusetts and Ontario to North Dakota, south to Texas and Georgia.
ILLINOIS DISTRIBUTION: Common throughout the state.

The alternate leaves on the upper stem and the solitary flowers separate this species from the following one.

Although several authors attribute 5 or 7 calyx lobes and petals occasionally to this species, I have never observed more or less than 6 in all the Illinois specimens examined.

Short (1845) called this species *L. hyssopifolia*, but this Linnaean binomial applies to an entirely different species.

Specimens examined.--CARROLL: Roadside, Verts 334 (SIU). COLES: Near Charleston, Ebinger 4553 (SIU). COOK: N. of Harvey, Winterringer 1599 (ISM). FRANKLIN: Royalton, Fuller & Welch 382 (ISM). GALLATIN: Roadside, Swayne & Bailey 1059 (SIU). HENDERSON: Roadside, Johnson s.n. (SIU). JACKSON: Finney, Mohlenbrock 5474 (SIU). LAKE: Wet meadow, Richardson 513 (SIU). LAWRENCE: W. of Lawrenceville, Sivert s.n. (ISM). McDONOUGH: S.W. of Macomb, Krauser 31 (ISM). PERRY: E. of DuQuoin, Embing s.n. (SIU). ST. CLAIR: Railroad, O'Neill 9000 (SIU). SALINE: Roadside, Voigt & Weber 1872 (SIU). TAZEWELL: Illinois River, Chase 3209 (SIU). WILL: Open field, Schoenershoven 34 (SIU). WILLIAMSON: N. of Creal Springs, Bailey & Swayne 2544 (SIU).

2. *LYTHRUM SALICARIA* L. Sp. Pl. 446. 1753.

Herbaceous perennial with taproots. Stem 4-angled, slightly winged, glabrous to slightly puberulous, erect, up to 95 cm tall. Leaves opposite or whorled, simple, lanceolate to linear-lanceolate, acute at the apex, truncate to cordate at the base, glabrous to subtomentose above, puberulous to velutinous below, especially along the veins, lighter on the lower surface, up to 10 cm long, up to 1 cm wide, sessile; stipules absent.

Flowers trimorphic, numerous, in dense terminal spikes or racemes, sessile to subsessile on pedicels up to 2 mm long. Calyx tubular to campanulate, 12 ribbed, up to 8 mm long, subtomentose to densely velutinous along the ribs, divided above into 6 lobes, with 6 appendages between the lobes, the appendages up to 2x as long as the sepal lobes. Petals 6, free, ovate to obovate, red-purple, glabrous, up to 10 mm long. Stamens 12, diadelphous, 6 strongly exerted, 6 short-exerted, attached to the calyx tube. Pistil 1; style 1, of three lengths; stigma capitate; ovary superior. Fruit a tubular to tubular-urceolate capsule with numerous seeds.

COMMON NAME: Spiked Loosestrife.
HABITAT: Wet ditches, meadows, swamps.
RANGE: Newfoundland to Minnesota, south to Missouri and Virginia; British Columbia to California; Eurasia.
ILLINOIS DISTRIBUTION: Occasional in the northeastern counties, but apparently less common elsewhere.

In its broad range, this species is "locally abundant, often too aggressive in choking out native vegetation" (Fernald 1950).

Gleason (1952) describes this species as being composed of two varieties, var. *tomentosum* with white tomentose calyx and bracts and var. *vulgare* with calyx and bracts thinly pilose, but states that intermediate forms occur. The latter variety corresponds closely to the typical variety as described by Fernald (1950) and others. Mohlenbrock (1975) includes var. *tomentosum* within his concept of the species *L. salicaria*. The amount of pubescence on specimens observed is quite variable. I do not believe that this species should be separated into distinct varieties.

Specimens examined.--CARROLL: Roadside, Verts 256 (SIU). CHAMPAIGN: Waste area, Bray 8666 (SIU). LAKE: E. of Wauconda, Winterringer 14240 (ISM). MACON: Cultivated, Smith s.n. (ISM). MARSHALL: E. of Lacon, Winterringer 7997 (ISM). WINNEBAGO: Rockford, Fell F47-271 (ISM).

4. *PEPLIS* L. Sp. Pl. 332. 1753.--Water Purslane.

Aquatic or semi-aquatic herbs with opposite leaves. Flowers minute, axillary; calyx campanulate with 4 lobes at the apex, with no appendages between the lobes; petals absent; stamens 4; capsule globose.

This genus contains the smallest plants in the Illinois Lythraceae. It is also the only member without petals.

Although Gleason (1952) and others use the name *Didiplis* for this genus, *Peplis* has priority.

A north temperate genus with three species.

The following is the only species found in Illinois:

1. *PEPLIS DIANDRA* Nutt. ex. DC. Prodr. 3:77. 1828.
Didiplis linearis Raf. All. Journ. 177. 1833.
Hypobrichia nuttallii Torr. & Gray, Fl. N. Am. 480. 1840.
Ammannia nuttallii (Torr. & Gray) A. Gray, Man. Bot. ed. 4, appenda p. xcii. 1863.
Didiplis diandra (Nutt.) Wood. Am. Bot. & Fl. 124. 1870.

Herbaceous perennial with fibrous roots, often rooting at the lower nodes. Stems 4-angled, glabrous to slightly glandular, weakly erect to prostrate, up to 25 cm tall. Leaves opposite, simple, the submerged leaves linear, the emersed leaves linear to elliptic, acute to rounded at the apex, tapering to truncate, and decurrent at the base, glabrous, darker on the upper surface, up to 3 cm long, up to 3.5 mm broad, sessile; stipules absent.

Flowers few, solitary, axillary, sessile. Calyx campanulate, up to 1.5 mm long, glabrous, divided above into 4 lobes. Petals none. Stamens 4, included, attached to the calyx tube. Pistil 1; style 1, very short; stigma capitate; ovary superior. Fruit globose capsule with numerous minute, elongate seeds.

COMMON NAME: Water Purslane.
HABITAT: Shallow waters, edges of lakes, ponds and rivers.
RIVERS: Virginia to Ohio and southern Minnesota, south to Nebraska, eastern Texas and Florida.
ILLINOIS DISTRIBUTION: Scattered in the western half of Illinois, much less common eastward.

Specimens examined.--HENDERSON: Near Oquawka, French s.n. (SIU). JACKSON: Cedar Lake, Heineke 1794 (SIU). JEFFERSON: S. of Mt. Vernon, Dolbeare 1341 (ISM). MASON: Dry pond, Rexroat 3386 (ISM). PIKE: S.W.

of Meredosia, Rexroat 6379 (ISM). POPE: Near Bell Smith Springs, Bailey & Swayne 3118 (SIU). ST. CLAIR: Lotus Lake, O'Neill s.n. (SIU). UNION: Union County State Refuge, Bailey & Swayne 1478 (SIU). WILLIAMSON: Muddy soil, Wilson 1463 (SIU).

5. *ROTALA* L. Mant. 2:175. 1771.

Herbs with opposite or whorled leaves. Flowers inconspicuous and axillary or in terminal racemes; calyx with 3-6 lobes above, with or without appendages between the lobes; petals present or absent, stamens 1-6; capsule septicidal.

Approximately 40 species, chiefly of the Old World tropics; 2 species in tropical America.

Only the following species occurs in Illinois:

1. *ROTALA RAMOSIOR* (L.) Koehne in Mart. Fl. Bras. 13:194. 1875.
   Ammannia ramosior L. Sp. Pl. 120. 1753.
   Ammannia humilis Michx. Fl. Bor. Am. 1:99. 1803.
   Rotala ramosior var. *typica* Fern. & Grisc., Rhodora 37:169. 1935.
   Rotala ramosior var. *interior* Fern. & Grisc., Rhodora 37:169. 1935.

Herbaceous perennial with fibrous roots. Stem usually 4-angled, glabrous, erect to slightly procumbent, often rooting at the nodes, up to 60 cm tall. Leaves opposite, simple, linear-spatulate, obtuse at the apex, tapering to the base, glabrous, darker on the upper surface, up to 5 cm long, up to 1 cm broad, sessile to very short petiolate; stipules none.

Flowers solitary in the axils of the leaves, sessile. Calyx globose to urceolate, up to 4 mm long, glabrous, divided above into 4 lobes with 4 triangular appendages between the lobes. Petals 4, free, obovate, white to pink, glabrous, up to 1.8 mm long, caducous. Stamens 4, minute, included, attached to the calyx tube. Pistil 1; style 1, included; stigma capitate; ovary superior. Fruit a globose to urceolate capsule with numerous small seeds.

COMMON NAME: Rotala.
HABITAT: Moist soil, shorelines.
RANGE: Massachusetts to Minnesota, south to Texas and Florida; Washington to California; tropical South America.
ILLINOIS DISTRIBUTION: Scattered throughout the state.

This species might be confused with the following two species of *Ammannia*, but is distinguished from the latter by normally having only one flower per leaf axil and tapering leaf bases. *Ammannia* has flowers in cymes in the leaf axils and cordate or truncate leaf bases.

Gleason (1952) recognizes var. *interior* as being generally more robust with sessile to subsessile leaves, while the typical form is said to have definite petioles. Jones and Fuller, et al., (1955) do not

recognize this variety. Although there appears to be some variation in the leaf base in Illinois material, the differences do not seem to justify varietal differentiation.

Michaux' *Ammannia humilis*, a binomial used by Illinois botanists until Brendel's Flora Peoriana (1887), is synonymous with *R. ramosior*.

Specimens examined.--ADAMS: S.E. of Quincy, Rexroat 4226 (ISM). ALEXANDER: Horseshoe Lake, Houston 182 (SIU). CASS: S.E. of Beardstown, Winterringer 15041 (ISM). CUMBERLAND: S. of Greenup, Dolbeare 3112 (ISM). HAMILTON: Mayberry Hill, Colclasure 106 (SIU). JACKSON: Carbondale City Lake, Sands s.n. (SIU). LEE: S. of Amboy, Chase 169198 (ISM). PERRY: Pinkneyville Reservoir, Stookey & Fore 599 (SIU). POPE: Klondike Spring, Schwegman 1943 (SIU). PULASKI: Between Wetang and Ullin, Winterringer 5965 (SIU). RANDOLPH: Coulterville Reservoir, Stookey & Fore s.n. (SIU). SCOTT: N.E. of Naples, Rexroat 4167 (ISM). UNION: Pine Hills, Bailey & Swayne s.n. (SIU). WASHINGTON: Nashville City Reservoir, Windler s.n. (SIU). WAYNE: Fairfield Reservoir, Stookey s.n. (SIU). WILLIAMSON: N.E. of Carterville, Bell s.n. (SIU).

6. *AMMANNIA* L. Sp. Pl. 119. 1753.

Herbs with narrow sessile leaves. Flowers in small axillary clusters of 3-5 or rarely solitary; calyx globose or campanulate, usually with 4 short lobes above and 4 appendages between the lobes; petals present or absent; stamens 4 or 8; capsule irregularly dehiscent.

Approximately 20 species, mostly in warmer parts of the Old World.

The following represent the only Illinois species:

KEY TO THE SPECIES OF *AMMANNIA* IN ILLINOIS.

1. Flowers sessile or on pedicels up to 1 mm long---------- 1. *A. coccinea*
1. Flowers pedicellate, the pedicels at least 1 mm long---------- 2. *A. auriculata*

1. *AMMANNIA COCCINEA* Rottle. Hort. Hav. Descr. 7. 1773.
Ammannia latifolia Torr. & Gray, Fl. N. Am. 1:480. 1840.

Herbaceous annual with fibrous roots. Stems 4-angled, freely branched, glabrous, erect, up to 70 cm tall. Leaves opposite, simple, linear to linear-lanceolate, acute to rarely rounded at the apex, truncate to cordate-clasping at the base, glabrous, slightly lighter on the lower surface, up to 10 cm long, up to 1.2 cm wide, sessile; stipules absent.

Flowers in cymes in the upper leaf axils, sessile to subsessile on glabrous pedicels up to 1 mm long. Calyx campanulate to urceolate with prominent ridges, up to 3.5 mm long, glabrous, divided above into 4 lobes with 4 horn-like appendages between the lobes. Petals 4, free, spatulate, purple, glabrous, up to 3.5 mm long, caducous. Stamens 4-8, exerted, attached to the calyx tube. Pistil 1; style 1, exerted; stigma capitate; ovary superior. Fruit a globose capsule with numerous small seeds.

COMMON NAME: Ammannia.
HABITAT: Edges of ponds and lakes and similar wet areas.
RANGE: New Jersey to Washington, south to California, Texas and Florida; Central and South America.
ILLINOIS DISTRIBUTION: Common throughout most of the state, except for the northernmost tier of counties.

This species is differentiated from the following species by its sessile or subsessile flowers.

Brendel (1887) was apparently the first Illinois botanist to use the binomial *A. coccinea* for this species. Previous workers all used Torrey and Gray's *A. latifolia*.

Specimens examined.--BROWN: S. of the Locks, Rexroat 6357 (ISM). CALHOUN: N. of Bellview, Winterringer 8773 (ISM). CARROLL: Roadside, Verts 334 (SIU). CUMBERLAND: N.W. of Toledo, Winterringer 5882 (ISM). EDWARDS: Near Albion, Winterringer 2132 (ISM). FRANKLIN: Lake Benton, Stookey & Fore 654 (SIU). FULTON: W. of Havana, Rexroat 6224 (ISM). JACKSON: Carbondale City Lake, Sands 404 (SIU). MACON: S. bank of Finley Creek, Shildneck C-4281 (SIU). MERCER: Near New Boston, Wunderlin & Chapman 281 (SIU). McDONOUGH: Roadside, Myers 3149 (SIU). PULASKI: N.E. of New Zion Church, Henderson 320 (SIU). RICHLAND: N. of Olney, Scherer 287 (ISM). ST. CLAIR: Near Dupo, Neill 956 (ISM). WABASH: S. of Keensburg, Winterringer 9794 (ISM). WASHINGTON: Shoreline, Windler s.n. (SIU).

2. *AMMANNIA AURICULATA* Willd. Enum. Pl. Hort. Berol. 1:7. 1809.
Ammannia senegalensis DC. Prodr. 3:77. 1828.

Herbaceous annual with fibrous roots. Stems 4-sided, freely branched, glabrous, erect, up to 60 cm tall. Leaves opposite, simple, linear to linear-lanceolate, acute at the apex, auriculate-clasping at the base, glabrous, darker on the upper surface, up to 9 cm long, up to 1 cm wide, sessile; stipules absent.

Flowers cymose in the upper leaf axils on glabrous pedicels up to 3 mm long; peduncles glabrous, up to 5 mm long. Calyx campanulate with prominent ridges, up to 2.5 mm long, glabrous, divided above into 4 lobes with as many horn-like appendages in the sinuses. Petals 4, free, spatulate, purple, glabrous, up to 2 mm long. Stamens 4, exerted, attached to the calyx tube. Pistil 1; style 1, exerted; stigma capitate; ovary superior. Fruit a globose capsule with numerous small angular seeds.

COMMON NAME: Stalked Ammania
HABITAT; Moist borders of lakes and ponds and similar wet areas.
RANGE: Indiana to South Dakota, south to Mexico, New Mexico and Mississippi.
ILLINOIS DISTRIBUTION: Known only in three western counties.

This species is divided by Koehne (1903) into three varieties. The typical var. *auriculata,* from several African countries, is said to possess 8 stamens and capillary pedicels. Var. *bojeriana,* also from Africa, has 4 stamens, thick pedicels, and puberulent calyces. Var. *arenaria* is distinguished by having 4 or rarely 8 stamens, thick pedicels, and a glabrous calyx. The range of this variety includes America. There seems to be sufficient basis for these varietal differentiations. Our species belongs to var. *arenaria.*

Koehne (1903) further segregates var. *arenaria* into five forms based primarily on the number of flowers in the inflorescence, relative length of the style to the capsule, and the length of the pedicel. I choose not to recognize these forms in this study since four of them are Old World and have not been examined.

DeCandolle's *A. senegalensis* of 1828, a taxon different than Lamarck's *A. senegalensis* of 1791, is equivalent to *A. auriculata.*

Specimens examined.--CASS: Wet, sandy soil, Rexroat 10484 (ISM). JACKSON: Lake Murphysboro State Park, Mohlenbrock s.n. (SIU).

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PRESETTLEMENT FOREST COMPOSITION OF THE CENTRAL SANGAMON RIVER BASIN, ILLINOIS

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ABSTRACT

Reconstruction of original forest composition from records of the United States General Land Office Surveys of central Illinois, and comparison with topography, soils, and present forest studies indicate that presettlement forests on uplands and on the windward sides of major streams were dominated by black oak and hickory, with increased frequency of white oak on the leeward sides of streams and on slopes. Both slope and upland forests show greater amounts of black oak and hickory than do present forest stands, reflecting a comparatively xeric forest despite relatively mesic climatic conditions of the "Neoglacial" or "Little Ice Age" just ending; forest composition is attributed to fires burning into the forest from adjacent upland prairies.

INTRODUCTION

At the time of European settlement (1819-1823), the landscape of central Illinois was dominated by tallgrass prairie with forest limited to the floodplain, steeper slopes bordering the streams, and isolated "prairie groves" on the uplands. The high fertility of the land and its great potential economic value attracted intensive settlement and, as a result, the tallgrass prairie has been almost entirely destroyed as a community. The origin and history of the Prairie Peninsula, however, have long been of interest (Geis and Boggess 1968). The distribution of prairie and forest prior to settlement was mapped by Vestal (1931) from soil survey reports and refined considerably by Anderson (1970) on the basis of United States General Land Office Survey records. Although prairie covered approximately 70% of central Illinois and has been frequently studied (Anderson 1970), the other 30% of the region, forested during presettlement times, is of less economic value, and has generally been neglected. This study examines the distribution and composition of the presettlement forest in central Illinois and suggests some factors that may have been instrumental in its development.

Many studies of the modern vegetation have been conducted in central Illinois, although for the most part in the area east of the limit of Wisconsinan glaciation (Calef 1953, Boggess 1964, Boggess and Bailey 1964, Boggess and Geis 1967, Root *et al.* 1971). This study of the presettlement vegetation of central Illinois covers the relatively homogeneous Sangamon River basin from south and west of the limit of Wisconsinan glaciation (Fig. 1) to its confluence with Salt Creek, where the soils and topography become more similar to those bordering the Illinois and Mississippi River valleys (Schwegman 1973). This area includes 1,750 km^2 (676 mi^2) and has basically uniform topography, substratum, and climate.

The Sangamon River basin is underlain by Illinoian drift covered by as much as 20 to 90 m of Wisconsinan age loess. Because the area is developed on an older land surface, it has better established drainage patterns than the more recently glaciated areas to the north and east. The topography is generally flat, except for the relatively steep valley slopes bordering the Sangamon River and its tributaries which are incised 15 to 30 m below the general upland.

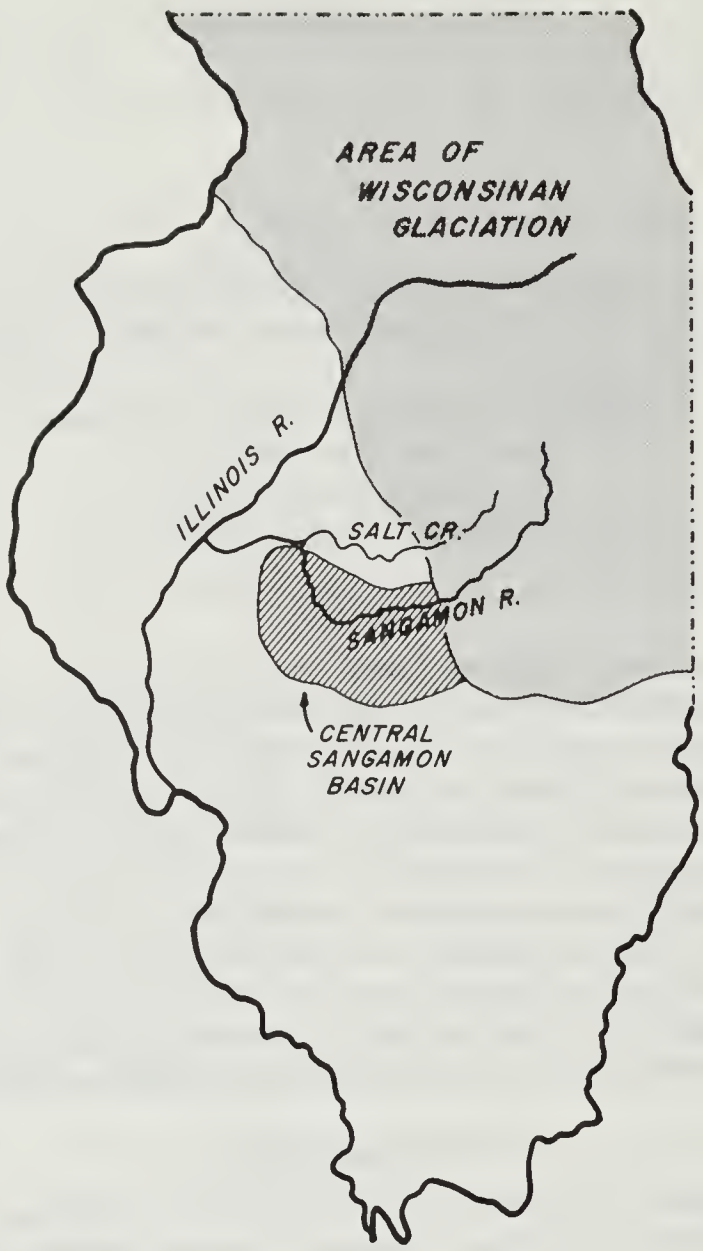

Fig. 1. Map of Illinois showing the central Sangamon River Basin.

The soils of the upland forests and slopes, formed from thick loess, for the most part belong to the Clary-Clinton-Keomah and Stookey-Alford-Muren soil associations. They are acid, with a tendency to be low in organic matter and nutrients, and have good to very good water-holding capacities. They are similar to the forest soils of eastern Illinois in fertility, texture, permeability, and drought resistance, although somewhat better drained (Fehrenbacher *et al.* 1968). Windblown sand occurs in dunes on the uplands bordering the Sangamon River Valley in this area, with the maximum extent of sand being attained on the eastern and southern borders of the valley (Bergstrom *et al.* 1976).

The climate of central Illinois is dominated by dry continental air extending from the western Plains. During the summer, this air mass is contracted westward by the northward movement of moist Gulf air bringing normal summer precipitation; if this northward movement fails to occur the dry western air predominates producing droughts and higher temperatures (Borchert 1950). The climate of Springfield is typical of the area (Denmark 1969): Average annual temperature, 12°C (53.6°F); growing season, 186 days; average annual precipitation, 88.47 cm (34.83''), highest between April-July; average relative humidity (noon), 59%; prevailing winds and speed, south 19.2 km/h (12 mph)-annual.

Transeau (1935) reported many distinctive differences between the prairie region and adjacent forested areas: A lower annual and seasonal precipitation/evaporation ratio in the prairie, lower midsummer relative humidity, a higher percent of the annual precipitation coming during the growing season rather than the winter, and greater variability of precipitation in both areal extent and timing. On a regional basis, these factors favor the establishment

of prairie over forest. Once prairie is established, other factors become important in the continued exclusion of forest: The superior water utilization by grasses, the shading out of young tree seedlings, the incapability of seedling roots to penetrate thick prairie sod, and the tolerance of the prairie plants to fires which would kill young tree seedlings. Trees, therefore, are primarily confined to slopes where erosion breaks the sod cover, and young trees are protected from sun and wind dessication as well as from sweeping prairie fires.

Few remnants of the presettlement forest remain in existence today; those that do occur primarily adjacent to streams and only rarely on the flat uplands (Gleason 1913, Boggess and Geis 1967). The valley slope and upland forests belong to the Oak-Hickory association described by Braun (1950). The dominant species are white oak *(Quercus alba),* with red oak *(Q. rubra),* black oak *(Q. velutina),* shagbark hickory *(Carya ovata),* slippery elm *(Ulmus rubra),* and American elm *(U. americana).* The slightly drier conditions on the upper south-facing slopes are frequently reflected by the absence of more mesic species such as red oak and basswood *(Tilia americana)* (Bell 1974) from these areas. The floodplain forests are dominated by silver maple *(Acer saccharinum),* with green ash *(Fraxinus pennsylvanica),* hackberry *(Celtis* spp.), bur oak *(Q. macrocarpa),* and shingle oak *(Q. imbricaria)* among the more common species (Bell 1974, Johnson and Bell 1975).

METHODS

The data used in the reconstruction of the presettlement forest composition of the central Sangamon drainage were compiled from the field notes of the original United States General Land Office Survey (1819-1823) on file in the State Archives, Springfield, Illinois. The surveys were the first step in dividing the land for settlement and consisted of setting up townships each six miles square divided into 36 mile square sections.

The instructions applicable to this area during the period of the survey were issued in 1815 by Surveyor General Edward Tiffin with additional rather vague directives issued periodically thereafter (Stewart 1935). Each 40 chains (½ mi., 0.8 km) a marker was set and two trees emblazened with the survey data. The distance, diameter, and species of these trees were recorded. At the end of each mile, the soils and vegetation (trees and undergrowth) of that mile were described and the suitability of the land for settlement evaluated. The surveyors' instructions included criteria for choosing bearing trees if they occurred within a "reasonable" distance. "Reasonable" distance was not specified in the initial instructions, but by 1840 it was defined as within 10 chains (⅛ mi., 400 m) (Stewart 1935).

Presettlement forest composition and structure were reconstructed by methods outlined by Cottam and Curtis (1956). To make the survey data compatable with modern forest studies in central Illinois, importance values (I.V.) were calculated by adding the relative density and relative dominance (basal area) of each species (Boggess and Geis 1967). Based on the calculation of random pairs (Cottam and Curtis 1956, Anderson and Anderson 1975), tree density for the total area was 36 trees/ha. However, random pairs does not take into consideration the large number of points (up to 64%) that have only one tree, a second being too distant to include, and is therefore biased towards too high a tree density. For this reason, tree density was determined by applying the formula $(Q_1/0.5)^2$ = Mean Area, where Q_1 is the distance to the nearest tree (Cottam and Curtis 1956, Delcourt and Delcourt 1974). Surveyor bias, a frequent problem in some surveys, was found to be insignificant when checked by either chi-square (Bourdo 1956) or by analysis of variance (Delcourt and Delcourt 1974).

Topographic information (slope, category aspect, elevation) was recorded for each witness corner from the following USGS 15-minute topographic maps: Divernon Quad. (1922), Taylorville Quad. (1923), Waverly Quad. (1924), Petersburg Quad. (1933), Tallula Quad. (1940), Springfield Quad. (1940), Mechanicsburg Quad. (1954). Soil types were determined from county soil maps (Hopkins *et al.* 1912, Fehrenbacher *et al.* 1950, Fehrenbacher and Odell 1953). Since the composition of bottomland forests changes in response to a moisture and flooding gradient (Bell 1974), the relationship between vegetation and stream size was examined by ranking the streams (following Strahler 1957) with the smallest streams (on

15-minute topographic maps) ranked 1, and the stream reach below the confluence of two like order streams ranked the next higher order, etc. The rank of the stream was determined for each bottomland point at which witness trees were recorded.

RESULTS

Data from approximately 2,000 quarter section and section corner points was used in the analysis. Upland (level) points accounted for 65.2% of the total points, while valley slope and bottomland were 14.3% and 20.5% respectively. Prairie occurred at 67.4% of all points, including not only the majority of upland points (76%), but the majority of bottomland points as well (65.8%) and 29% of the points occurring on slopes, despite environmental factors favoring the growth of trees in slope situations. The slope angle was also found to be a critical factor in determining vegetation cover. In a sample of 944 points for which slope was determined, most points with a slope in the 5-7% category or greater were forested while relatively flat-lying points were more often prairie covered (Fig. 2). Points in the 5-7% slope category were occupied by both forest and prairie, with 88% of such points on the north and east sides of second-order or larger streams being forested, compared to 35% of those on the south and west sides of such streams. This distribution may be interpreted as the blockage by stream valleys of prairie fires being blown towards the northeast before prevailing winds, a phenomenon originally described by Gleason (1913, 1923).

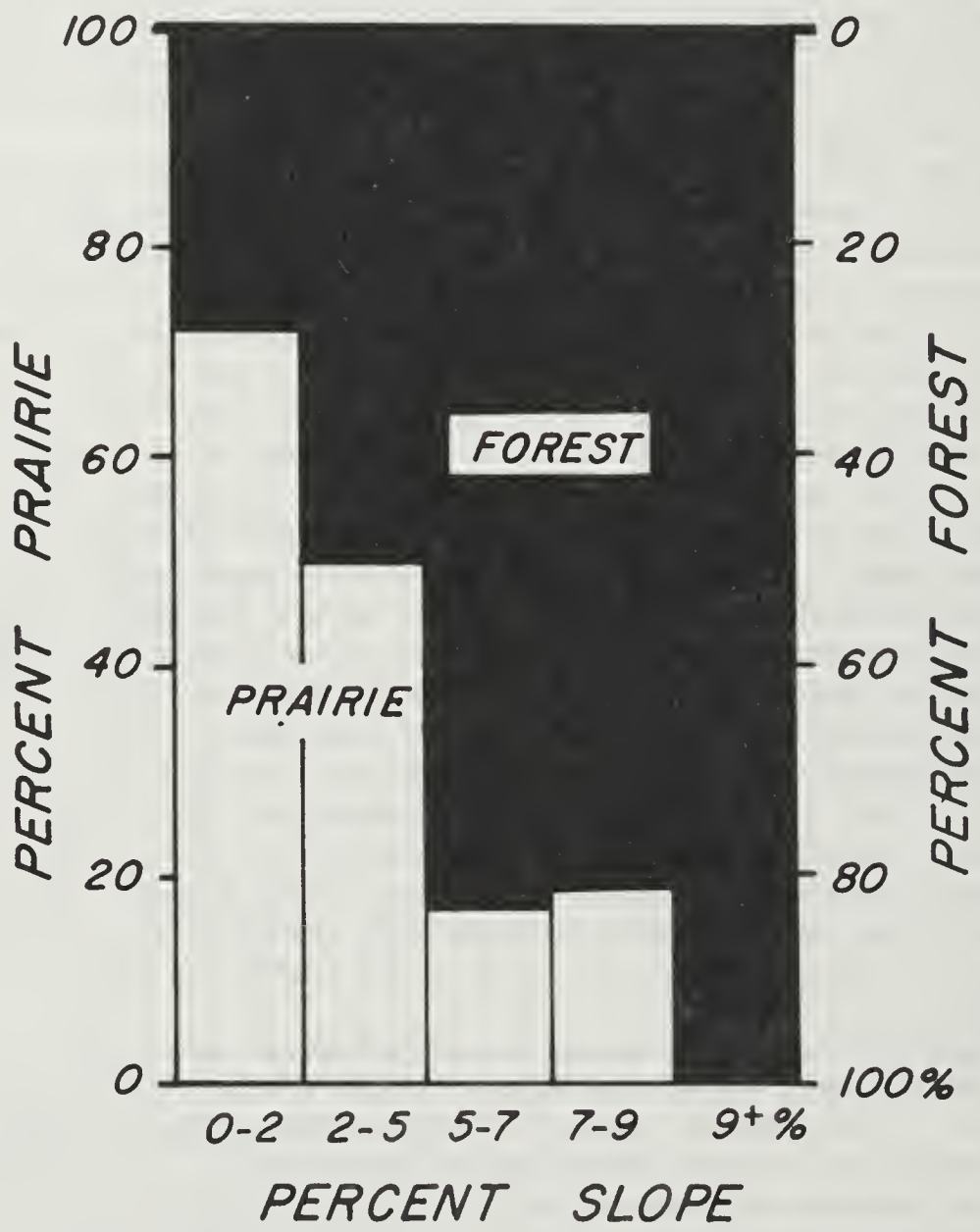

Fig. 2. Relationship between slope category and type of vegetation based on presettlement vegetation of the central Sangamon River Basin, Illinois.

As in all GLO surveys, the surveyors in central Illinois were obligated to choose witness trees at least large enough to have room for their enscribed information (Bourdo 1956, Anderson and Anderson 1975). As a result, tree diameters are over-represented in the 12" (30.5 cm) diameter class and to some extent in the 10" (25.4 cm) and 14" (35.6 cm) diameter classes, while the 8" (20.3 cm), 6" (15.2 cm) and 4" (10.2 cm) classes are increasingly under-represented. The larger diameters tend to be grouped at 18" (15.7 cm), 24" (61.0 cm), 36" (91.4 cm), and so forth into 6" diameter increments. Larger diameters also tend to be under-represented since the surveyors were also interested in the longevity of the potential witness tree (Bourdo 1956). When allowances are made for bias towards selecting trees of certain diameters, the diameter class distribution in the central Sangamon drainage approximates that of an undisturbed old-growth forest in which the smallest diameter class is most highly represented and frequency falls off with increasing age and size (Bourdo 1956). Diameter class distributions between uplands and slopes are nearly identical. It appears that only the most catastrophic environmental events might be recorded in such a tree diameter record, and none is evident.

Forest density, calculated from the survey data, is low (random pairs: 36 trees/ha; nearest tree: floodplain forest 20.6 trees/ha, slopes 41.5 trees/ha, upland forests 10 trees/ha) compared to the 84-108 trees/ha greater than 13" in diameter found in recent forest studies in Illinois (Boggess 1964; Boggess and Geis 1966, 1967; Jackson and Petty 1971; Root *et al.* 1971). These densities are however more similar to those of other midwestern presettlement forests reported by Anderson and Anderson (1975) (84 trees/ha total or 15.8 trees/ha in savannah) or Cottam (1949) (35.8 trees/ha for oak openings in southwestern Wisconsin).

TABLE 1

RELATIVE IMPORTANCE VALUES FOR PRESETTLEMENT FORESTS OF THE CENTRAL SANGAMON BASIN

SPECIES	FLOODPLAIN	SLOPE	UPLAND
Ulmus spp. (elm)	44.6	14.4	12.0
Platanus occidentalis (sycamore)	24.0	< .1	0.1
Quercus velutina (black oak)	25.6	67.6	78.8
Carya spp. (hickory)	19.0	26.0	41.7
Q. alba (white oak)	14.8	69.5	50.8
Acer saccharinum (maple)	11.6	0.7	–
Gleditsia triacanthos (honey locust)	10.3	2.5	1.0
Fraxinus spp. (ash)	9.9	0.9	1.3
Juglans nigra (black walnut)	19.5	4.1	4.1
Celtis spp. (hackberry)	5.4	3.1	0.2
Q. palustris (pin oak, spanish oak)	2.7	1.2	3.2
Q. rubra (red oak)	3.3	–	0.1
Populus deltoides (cottonwood)	2.4	–	–
Acer saccharum (sugar maple)	0.9	2.0	0.1
Morus rubra (mulberry)	0.9	1.4	0.1
Prunus spp. (cherry)	0.9	1.6	1.2
Aesculus glabra (buckeye)	0.8	0.8	0.4
U. rubra (slippery elm)	0.8	0.1	0.1
Tilia americana (basswood, linden)	–	1.2	7.6
Q. macrocarpa (bur oak)	–	0.7	–
Gymnocladus dioicus (Kentucky coffee tree)	–	0.2	–
Q. marilandica (blackjack oak)	–	0.7	0.1
Cercis canadensis (redbud)	–	0.1	–
Sassafras albidum (sassafras)	–	–	0.5

TABLE 2

IMPORTANCE VALUES FOR PRESETTLEMENT UPLAND FORESTS COMPARED TO PRESENT FOREST STANDS FROM CENTRAL ILLINOIS (I.V. GREATER THAN 5.0)

	PRESENT				PRESETTLEMENT	
SPECIES	BROWNFIELD WOODS[1] (PRAIRIE GROVE)	FUNK FOREST[2] (INTERMEDIATE)	ALLERTON PARK[3] (STREAMSIDE FOREST)	HART WOODS[4] ("XEROPHYTIC" STREAMSIDE FOREST)	SLOPE	UPLAND
Sugar maple	81.4	57.9	8.4	–	–	–
Red oak	24.0	5.4	12.2	11.1	–	–
Basswood	14.1	13.0	–	–	–	–
Hackberry	13.8	8.4	–	–	–	–
Ash	16.3	8.4	8.1	–	–	–
Black cherry	–	–	5.3	6.5	–	–
Silver maple	–	–	–	7.0	–	–
Elm	15.4	35.1	25.2	14.2	14.4	12.0
White oak	–	29.0	50.3	98.1	69.5	50.8
Black oak	9.4	7.3	30.6	57.4	67.6	78.8
Hickory	–	–	31.6	–	26.0	41.7

[1]Boggess and Bailey 1964.

[2]Boggess and Geis 1966.

[3]Boggess and Geis 1967.

[4]Root *et al.* 1971.

The dominant trees in the presettlement forest were black oak, white oak, and hickory, with high percentages of elm on the floodplain and walnut *(Juglans nigra)* on the terraces. Black oak was more commonly recorded than was any other species, including white oak. Some blackjack oak *(Q. marilandica)* was encountered on slopes and uplands as well as small amounts of sugar maple *(Acer saccharum)* and red oak on the slopes (Table 1).

As might be expected from modern studies, the presettlement floodplain forest possessed a large component of flood tolerant species: sycamore *(Platanus occidentalis),* cottonwood *(Populus deltoides),* silver maple, ash, hackberry, honey locust *(Gleditsia triacanthos)* and hawthorn *(Crataegus* spp.) (Table 1). However, there is also a high frequency of upland types such as white oak, black oak, and hickory, possibly indicating the non-specificity with which the land surveys reflect vegetation types, especially in areas of steep environmental gradients. A witness corner, occurring within a floodplain but near its edge, may contain both upland-slope and floodplain taxa.

When importance values of major tree species are compared with values from recent studies on forest stands in central Illinois, both the presettlement slope and upland forests appear most similar to a "xerophytic streamside forest" (Root *et al.* 1971) rather than to more mesic upland forest groves or streamside forests (Table 2).

If the distribution of major tree taxa are compared to slope and soil factors and their geographical relationship to major (perennial) streams examined (Fig. 3), several patterns emerge. Relatively fire-tolerant black oak was generally more abundant on the south side of major streams and on uplands. White oak, which requires higher levels of soil moisture, was most frequent on the north side of streams despite the relative dryness of such south facing slopes. Hickory was more abundant on the south sides of streams than on the north and although not identified to species by the surveyors, was probably shagbark hickory *(Carya ovata)* which sprouts vigorously after burning with relatively fire resistant new growth and rapidly fills vacancies in a forest (Curtis 1959). The species dominant on sandy soils (including sandy loams as well as dune sands) were influenced at least to some degree by topographic location (Fig. 3) and suggest that such areas may have had sufficiently good soil to support white oak, in addition to the black oak generally favored on poor sandy soils (Fowells 1965, Auclair 1976).

DISCUSSION

Climate is without doubt the single most important factor in the vegetational history of the Prairie Peninsula. The eastward expansion of the prairie in response to the drier and possibly warmer conditions during the "Hypsithermal" period, dating approximately 8000-4500 BP, is increasingly well documented (King 1977, Wright 1976). This dry period was followed by a return to more mesic climatic conditions culminating in a period of wetter and/or cooler conditions known as the "Neoglacial" or "Little Ice Age." King *et al.* (1976) speculate that the onset of this wetter/cooler period may have coincided with increases of arboreal pollen recovered from bottom sediment cores from Lake Michigan, reflecting advances of the forests surrounding the lake. Dated at about 800 BP, these wetter/cooler conditions would thus precede the establishment of Brownfield Woods, an upland mixed mesophytic forest, dated by Vestal and Heerman (1945) as about 400 to 600 years ago, or Trelease Woods, dated at about the same age on the basis of soil development (Boggess and Geis 1967). The "Neoglacial" did not end until the early 19th century, and the GLO surveys were therefore made towards the end of a relatively cool, moist period. At the time of the surveys (1815-1850), forests throughout the Midwest were encroaching onto the prairies (McComb and Loomis 1944, Howell and Kucera 1956, Boggess and Geis 1967).

In the present study, the distribution of prairie and forests suggests that streams as small as second-order were large enough to stop prairie fire advancement, even though at present such streams are dry during the fall when prairie fires are most likely to occur. It is likely that during late presettlement times such small streams may have actually been perennial rather than intermittent.

Prior to EuroAmerican settlement, the central Sangamon basin was primarily prairie, with

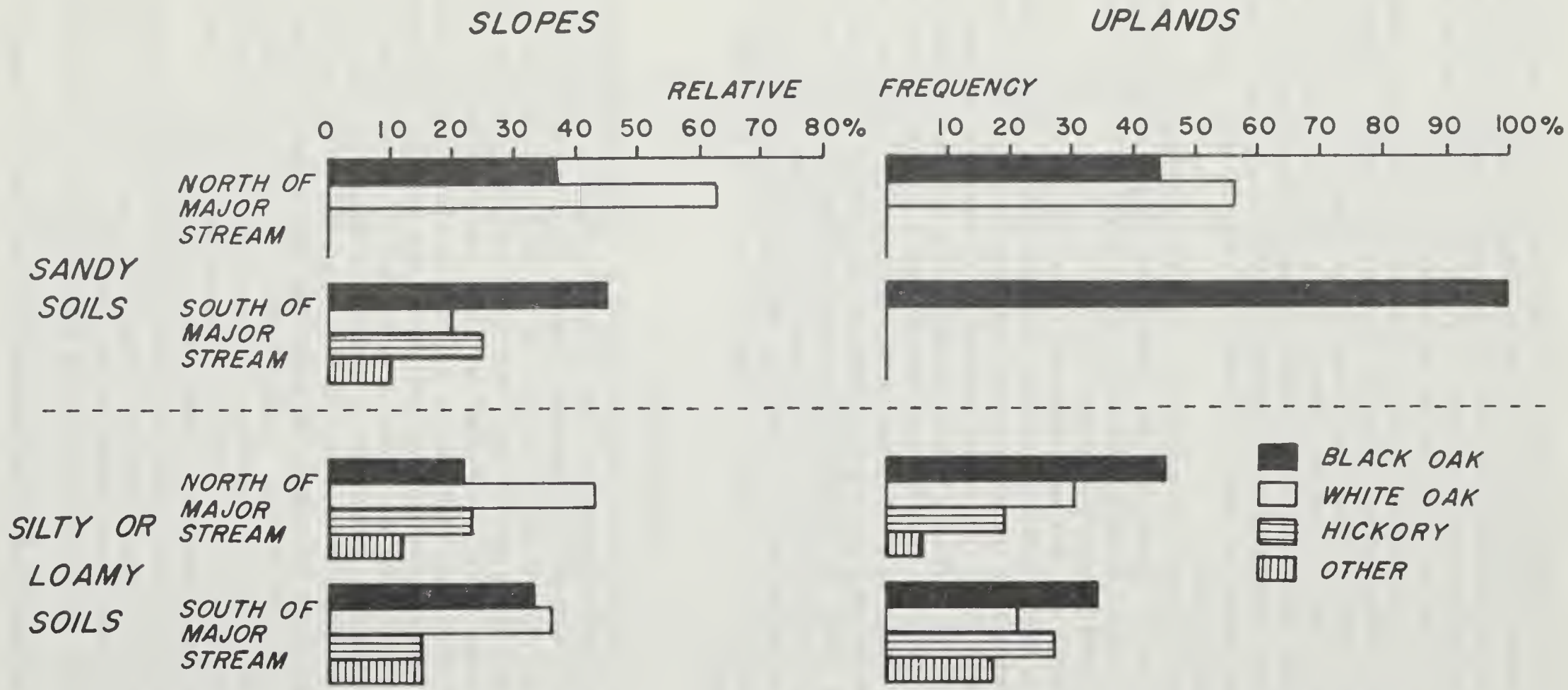

Fig. 3. Distribution of dominant tree taxa by topography, soil type, and geographical relationship to perennial (modern) streams.

forest limited to floodplains, slopes and to small upland patches. Compared to present forest stands, the presettlement slope and upland forests were both most similar to a "xerophytic streamside forest" (Root *et al.* 1971) even though I.V. for black oak compared to white oak are much higher than in any available modern forest analog from central Illinois. The upland forests are composed of more dry site species than those of the slopes, with higher percentages of black oak compared to white oak. This contrasts with present studies showing black oak to be more frequent on steeper slopes with less favorable moisture relations and less organic carbon (Soeriangera 1965, Root *et al.* 1971). At least in some instances it is clear that witness points lying on the north and east sides of streams were sheltered from fires spreading from the south and west, as shown by the higher number of forested points on the leeward sides of such streams, as well as by the relative distributions of black and white oak.

Forest succession in the Midwest may begin with red oak, white oak, bur oak or black oak as the pioneer species depending on how mesic the site. Succession may proceed through stands dominated by red elm to dominance by sugar maple on the most mesic sites, to white oak, shagbark hickory and black cherry on intermediate sites, or to bur oak and black oak on the most xeric (Peet and Loucks 1977). Any site may be maintained in a pre-climax condition by disturbance. Bur oak tends to favor calcareous soils (Fowells 1965) which do not occur widely in the Sangamon drainage. However, the 3 bur oak trees recorded by the surveyors average 84 cm (33") in diameter (compared to an average of 38 cm for all species) suggesting considerable antiquity on the part of these individuals. Black oak is extremely shade intolerant and unable to reproduce under shade (Fowells 1965). The main stem is susceptible to ground fire, but sprouts readily develop from the root collar. White oak is more shade tolerant than black oak and while sprouting prolifically and vigorously after burning, regenerates rather poorly from seed (Fowells 1965). Auclair (1976) found white oak to be restricted to protected locations on the lee of slopes with low moisture and fire stress. Red oak and sugar maple, although insignificant in the presettlement forests of central Illinois, are of interest because of their importance in modern forest stands. Red oak, while somewhat shade tolerant, is extremely susceptible to burning and regenerates poorly. Sugar maple is extremely shade tolerant and rapidly responds to openings in a forest, but it is also thin-barked and readily damaged by fire (Boggess and Geis 1966, Auclair and Cottam 1971). Wuenscher and Valiunas (1967) studying the River Hills region of central Missouri, concluded that the increase in sugar maple that has been observed since presettlement times is due to the absence of fire.

Curtis (1959) found I.V. for black oak and white oak in Wisconsin, comparable to those of the presettlement forests of the central Sangamon basin, only in southern dry forests and oak barrens, both of which he classifies as fire dependent, otherwise succeeding to more mesic forest types. Auclair (1976) also, in Wisconsin, found presettlement vegetation closely correlated with edaphic features except that the species composition of the "savannah" was related not to edaphic conditions, but to the fire-resistance of the individual species. In general, the soils of the central Sangamon drainage seem to be suitable for more mesic forests since similar soils support such forests at present (Boggess and Bailey 1964, Root *et al.* 1971, Boggess and Geis 1966), and some factor other than soils must have been instrumental in determining the forest composition.

It appears from our examination of the GLO survey records of central Illinois, that prior to settlement, the forests were dominated by fire tolerant trees, primarily black oak, white oak, and hickory. Sugar maple, a climax species with low fire tolerance, were rarely encountered. White oak, a tree of intermediate fire resistance was less important than in present forest stands which have undergone decreased burning since settlement. These presettlement forests probably became established at an earlier time in response to more favorable climatic conditions, but were maintained in their relatively early successional stage by fires burning into the forests from the adjacent prairies.

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SITE PRODUCTIVITY OF OAKS IN RELATION TO SOIL PROPERTIES AND TOPOGRAPHY IN NORTHERN ILLINOIS

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ABSTRACT

Cubic foot volume yields of black oak, white oak and red oak were correlated with soil properties of the A_1 and subsurface horizons plus topographical variables of 62 plots. Yield predicting equations based upon soil properties of the A_1 or subsurface horizons and topographical variables were computed by multiple regression. The best equations were obtained when based on subsurface horizons. A combination of variables from the A_1 and subsurface horizons gave the highest correlation, explaining 66 percent of the variation in yield. A yield predicting equation based on soil properties easily identified and quantified in the field that accounts for 42 percent of the variation in yield is given for forest management purposes.

The most widely accepted method of forest site evaluation in the United States is the direct estimation of forest yield from suitable trees. However, the limited range for extrapolation of site evaluation from this method severely curtails its usefulness. Relating yield to relatively stable environmental features such as soil and topography provides an alternative basis for forest site evaluation. This method is applicable where suitable forest trees are not present and can also be used in other locations having similar soils, topography, and climate.

Generally, soil and/or topographic factors that influence moisture supply have been shown to be most important in forest site evaluation. These factors include soil texture, stone content, soil depth, depth to mottling, water-holding capacity of the soil, slope gradient, physiographic position, aspect and the concavity or convexity of the slope. For example, McClurkin (15) found percent clay of the B horizon, depth to the least permeable layer, and 15-bar water retention

of the least permeable horizon to be the determining factors of site quality for oaks in western Tennessee and northern Mississippi. Carmean (4) concluded that soil depth, texture, stone content, and drainage the most important soil characters influencing growth of upland oaks in the central United States. Other investigators have reported similar findings (5, 10, 19).

The chemical content of the soil has also been used to predict productiveness of forest soils (8, 9, 11) but to a lesser extent than those factors related to available soil moisture. Individual cations, organic matter, percent base saturation, phosphorus, and nitrogen content of the soil have been used for this purpose (17, 20, 21).

One of the first steps necessary for intensive forest management is to determine the site quality of an area. With this information for each unit of land, forest managers can better determine which tree species or combination of species will most nearly meet the desired objective. This paper reports the relationship between the physical and chemical soil properties and topography to growth of black oak (Quercus velutina Lam.), white oak (Q. alba L.) and red oak (Q. rubra Michx.) in northern Illinois.

MATERIALS AND METHODS

The study was conducted in the Sinnissippi Forest in northwestern Illinois. The area is primarily an oak-hickory forest in the westernmost part of the eastern deciduous forest. Black oak and white oak usually in mixed stands predominate on the uplands sites while red oak is usually found mixed with white oak on the better sites.

The surficial geological deposits of the area consist of sand dunes, outwash, valley trains, alluvial deposits, loess, sandstone and limestone bedrock. Till is not extensive in the area but occurs as surficial deposits in isolated spots usually overburdened by loess.

In 1948 several hundred circular 1/5 acre plots were established in the Sinnissippi Forest for research purposes and to also aid in managing the forest. One hundred and ten of these plots were used in the present study. Only plots that were well stocked, at least during one of the three time spans covered by the four inventories conducted between 1949 and 1971, were considered. Further screening was based on species composition, age of the stand (91 to 110 age class) and soil characteristics.

Most of the field work for the study was conducted during the summers of 1971 through 1974. Soil uniformity, slope percent, and distance from center of the plot to the ridge of the slope was determined. Soil samples from major horizons of eleven soil series from 62 plots were taken to a depth of 60 inches or to a shallower depth coinciding with solum thickness. The soils included eight Hapludalfs, one Quartzipsamment, one Udipsamment, and one Hapludoll, ranging in texture from fine-silt to very fine sandy.

Soil samples were air dried, crushed and screened through a 2 mm sieve. Particle size distribution was determined by a simplified pipette method as described by Follmer (6). Available soil water for 36 representative soil samples were determined by difference between water held at 1/3 and 15 bars as described by Richards (18). Since there is a close relationship between soil texture and available soil moisture (12, 16), available water for the remaining soil samples were obtained by interpretation from soil texture.

Nitrogen was determined by a modified Kjeldahl method as described by Bremmer (3). Cation exchange capacity (CEC) was determined by saturating the soil with ammonium using neutral normal ammonium acetate. Exchangeable Ca and Mg were determined on the ammonium acetate leachate obtained from the CEC determination by atomic adsorption and Na and K on the acetate leachate by flame ionization. Percent base saturation (% BS) was determined by determining the proportion of the cation exchange capacity occupied by the exchangeable bases extracted by ammonium acetate. Available P (P_1 and P_2 tests) were determined by methods described by Bray and Kurtz[1](2). Soil pH was determined with a glass electrode on a 1:1 soil:water suspension.

Tree and mensurational data that included forest type, site quality, tree height, species, age, diameter at breast height (d.b.h.) and disposition (fate of previously measured trees) were collected in four inventories in 1949, 1954, 1963, and 1972. Total heights of sample trees were used to develop equations to obtain wood volumes for each forest type, age class, and site quality by the least squares method as described by Gevorkiantz and Olsen (7).

Growth expressed in cubic feet per acre per year was used as a measure of soil productivity. Although volume growth is more difficult to obtain than height growth it is preferred for hardwoods because it is more sensitive to environmental conditions. Furthermore, when some hardwood trees reaches a certain age, they may continue to increase in volume while their heights may remain constant (14).

Separate weighted averages were obtained for soil parameters of the A_1 horizon and the rest of the profile. This procedure was necessary since several samples were taken at various depths in each profile selected for sampling. If more than one sample was taken for a given horizon, an average weight of its value for each horizon was obtained according to the thickness of the soil layer in which it occurred.

Stepwise regression analysis was used to determine the contribution of each soil variable to yield. Equations were developed from 44 variables of the surface horizon and topographic variables, the subsurface horizons and topography, and a combination of the two soil horizons with topography.

RESULTS AND DISCUSSIONS

Simple Regression Correlations

Results of simple correlations between yield and selected soil and topographic variables showed that variables of the subsurface horizons

were better correlated with yield than with topographic or soil variables of the A_1 horizon. Yield was also better correlated with soil physical properties of both the A_1 horizon and subsurface horizons than with soil chemical properties of these horizons. Furthermore, logarithmic transformations of the soil variables were better correlated with yield than were nontransformed values.

Percent silt, available soil water, and their log transformations were better correlated with yield than any other soil variable, suggesting that water is the most limiting factor for tree growth in the study area. Other soil variables of the A_1 horizon significantly correlated with yield are N, percent clay and exchangeable Ca, and K. Significant correlations were also found between yield and CEC, and exchangeable Ca, Mg, and K of the subsurface horizon.

Multiple Regression Analysis

Exchangeable Na, percent very fine sand, and pH were not included in these regression analyses because Na was used in the computation of percent base saturation, sand was used in the calculation of available water and pH was used only as an informative variable as it was nearly uniform throughout the study plots.

A_1 Horizon:

A predicting equation calculated from topographic and soil variables of the A_1 horizon showed that log of available water, log of slope, log thickness of A_1 horizon, Ca, Mg, percent base saturation, P_2 test, P_1 test and K to be the significant variables. These variables explained 51 percent of the variation in yield.

Log of available water was the most potent variable in the equation explaining 25 percent of the variation. Slope and thickness of the A_1 horizon were significant in the equation even though both variables were weakly correlated with yield in the simple correlation analyses. The fact that thickness of the A_1 horizon appears in the equation is more than likely the result of the mechanics of the regression technique and probably no real relationship exist between this variable and yield for the majority of the soils. Ten of the eleven soil series in the study had similar ranges in thickness of the A_1 horizon, although the soils differed widely in productivity.

When topographic variables were removed from the equation, log percent silt, percent base saturation, log Mg, CEC and Mg were the most potent variables explaining 44 percent of the variation in yield.

Subsurface Horizons:

The yield-predicting value of soil variables from the subsurface horizons together with the topographic variables were tested by stepwise regression. Eleven variables were retained in the equation which explained 63 percent of the variation in yield. The log of available water was the most potent variable, followed by slope, log reciprocal of percent base saturation, log thickness of subsurface, P_2, K, log K, log percent sand, percent silt, log Ca and log N. Analyses of variance for subsurface horizons show that soil variables of this horizon in conjunction with

topography are superior to the surface variables for predicting yields. This superiority is attributed in part to the fact that erosion has removed part of the surface soil.

Surface and Subsurface Horizons:

Selected variables were screened by the stepwise regression technique to obtain a yield-predicting equation that included most variables. The best equation (with R^2 of .66) relating tree growth to soil and topographic variables was

$$\begin{aligned}\text{Yield} = {} & -164.66 + 18.49 \log (\%\ \text{silt subsurface}) + .25 \\ & (\%\ \text{Clay } A_1) + 11.19 \log \text{slope} + .22\ (\%\ \text{BS } A_1) + \\ & .42\ (\text{K subsurface}) - 34.74 \log (\text{N subsurface}) + \\ & 51.93 \log (1/\%\text{BS subsurface}) - 32.35 \log (P_1\ A_1) + \\ & 28.84 \log (P_2\ A_1) + 102.32 \log (\%\text{BS subsurface}) \\ & -.45\ (\%\text{BS subsurface}) - .31\ (\text{Mg } A_1)\end{aligned}$$

Distance from ridge has often been reported correlated with tree growth but this variable does not appear in the equation because all soil types studied except one, are underlain by permeable materials. This results in water percolating through the profile having a larger vertical vector component than a horizontal one. The net results are that percolating waters are out of reach of most tree roots. The other topographic variable (slope) was found positively correlated with yield in the equation. An increasing slope gradient would enhance the importance of the horizontal vectors component of water movement with the net result that soil water is more within reach of tree roots.

Logarithm of percent silt accounts for the highest variation in yield. In the soils of this study percent silt is highly correlated with percent available water in both the A_1 horizon and subsurface horizons. Inferences made about percent silt can also be made about available water. The relatively high percentage of silt in most of the soils, including some of the sandy soils, can be attributed to a substantial loess component in their parent material.

The nutrient status of the soils generally showed good correlations with yield except for P. Simple correlations between P of the A_1 horizon and yield were .13 and .19 for P_1 and P_2 tests respectively but were about .32 for Ca, N and K. The soil tests for P were developed and calibrated for agricultural crops and their use to assess the availability for certain tree species have limitations. Our results compare favorably with Alban (1) who obtained poor prediction values by the Bray and Kurtz (2) methods for P extraction, when comparing ten methods of extracting soil P for the purpose of site index prediction of red pine in Minnesota. However, the low correlations between yield and soil P tests can be partly attributed to the fact that P levels appear to be adequate for the growth of the oaks in our study.

The nutrient status of the soil, as measured in this study, is to some extent a limiting factor to tree growth. Exchangeable K in subsurface horizons has the highest correlation with yield of all the

nutrients and K deficiencies are most likely to occur in sandy soils of low CEC (13). If available soil moisture becomes a nonlimiting factor to tree growth in the study area, K probably would be the first nutrient to become limiting.

Exchangeable Mg was significantly correlated with yield but is believed to be nonlimiting to tree growth in the study area. Mg deficiences can occur due to imbalance of this element with Ca and K, but no such unfavorable ratios were observed in the soils of the study. Soil N was also correlated with tree growth but high correlations between this variable and other variables better correlated with yield preclude any definite conclusion.

In general, the nutrients seem to be correlated with tree growth, but soil physical conditions appear to be more limiting over the study area.

Prediction Of Yield For Management Purposes By Soil Features Easily Recognized In The Field

Yield prediction for forest management purposes using the best equation discussed above would be time consuming and expensive to obtain. Therefore, selected soil features easily recognized in the field were used to compute a yield-predicting equation which is given below:

$$\text{Yield} = 55.28 + 18.06 \log (\%\ \text{silt subsurface}) + .13\ (\%\ \text{clay } A_1) + 1.00\ (\text{thickness subsurface}) - 65.91 \log (\text{thickness subsurface})$$

This equation is less precise than the other equations in the study as indicated by the R^2 of .42. However, the small number of variables in this equation coupled with the ease in obtaining these values may justify its use for management purposes. In the above equation, silt content of the subsurface horizon is the most potent variable in the equation followed by clay of A_1 and thickness of subsurface. Percent silt of the A_1 horizon did not enter in the equation because of the strong correlation existing between it and the percent silt in the subsurface horizons. Percent silt of the subsurface horizons is a good estimator of potential available soil water in these soils. This variable in conjunction with thickness of the subsurface horizon can be a useful tool for yield prediction.

Percent clay of the A_1 horizon is a good estimator of some of the nutrient level of the soils studied. This fact is indicated by the high correlation between % clay and exchangeable Ca, Mg, and K (R^2 of .74, .72, and .61 respectively). A small increase in the R^2 would probably be obtained by substituting any of these nutrient elements for clay in the equation as they are better correlated with yield than clay. But these variables are costly to obtain and cannot be easily estimated in the field.

This yield-predicting equation is not applicable to other tree species and it should not be extrapolated very far outside the range of soil

characteristics and/or environmental conditions present in the area in which the study was conducted.

SUMMARY

An equation of soil and topographic variables was made with tree growth of the A_1 and subsurface horizons. Forty-four percent of the variation in yield could be accounted for by soil properties of the A_1 horizon with an additional seven percent by topographic variables. Percent silt in the A_1 horizon was the most potent variable in the equation. Other variables of this horizon correlated with yield were potential available water, percent slope, P_1, P_2, thickness of A_1 horizon, % BS, exchangeable Mg and exchangeable K.

Variables of the subsurface horizons were better predictors for yield than variables of the A_1 horizon. The subsurface soil variables with topographic variables accounted for 63 percent of the variation in yield. Potential available water, percent slope, % BS, thickness of subsurface horizons, P_2, exchangeable K, percent sand, percent silt, exchangeable Ca and total N of the subsurface horizons were correlated with yield.

Selected soil variables of the A_1 and subsurface horizons plus topographical variables explained 66 percent of the variation in yield. Log of percent silt of the subsurface horizons was the variable best correlated with yield accounting for 31 percent in the variation in yield. Other variables in this group correlated with yield were percent clay, % BS, exchangeable Mg, P_1 and P_2 of the A_1 horizons. In addition, exchangeable K, total N and % BS of the subsurface horizons plus percent slope were also correlated with yield.

An equation based on easily recognizable and quantifiable soil features was developed for forest management purposes. Percent silt of the subsurface horizons, percent clay of the A_1 horizon, thickness and log thickness of the subsurface horizons, in that order of importance, accounted for 42 percent of the variation in yield.

The most potent soil nutrients in the study were the exchangeable bases and total N. Potassium of the subsurface horizons was the nutrient best correlated with yield while Ca was the next best. Very low correlations were obtained between P_1 and P_2 phosphorus and yield.

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CANCELLATIVE PROPERTIES OF k-MODULAR AND k-DISTRIBUTIVE LATTICES

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Abstract. The purpose of this paper is to study the cancellation properties of classes of generalized modular lattices and of generalized distributive lattices. General lattice-theoretic properties of both k-modular and k-distributive lattices will be discussed. Necessary and sufficient cancellative properties will be given for each class of lattices.

Throughout the following, lattice precedence will be denoted by $\leq$, lattice joins by +, and lattice meets by juxtaposition.

Definition 1. A lattice L is weakly k-cancellative if $a \leq b$, $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \cdots \overset{<}{\neq} c_k$, $a + c_1 = b + c_1 = \ldots = a + c_k = b + c_k$ and $ac_1 = bc_1 = \ldots = ac_k = bc_k$ imply $a = b$.

Definition 2. A lattice L is k-modular if $a \leq b$, $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$ imply $b(a + c_1) + bc_k = a + bc_k$ or $c_2(a + c_1) + bc_k = c_1 + bc_k$ or $c_j(a + c_1) + bc_k = c_{j+1}(a + c_1) + bc_k$ for some $j = 2, \ldots, k - 1$.

Theorem 1. The following are equivalent for a lattice L:
(i) L is weakly k-cancellative.
(ii) L is k-modular.
(iii) L does not contain a sublattice isomorphic to N_{k+4}.

Proof. (i) implies (ii). Assume $a \leq b$, $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$ in a weakly k-cancellative lattice L. Suppose further that $d_1 = c_1 + bc_k \overset{<}{\neq} d_2 = c_2(a + c_1) + bc_k \overset{<}{\neq} \ldots \overset{<}{\neq} d_k = c_k(a + c_1) + bc_k$. Further, $e = a + bc_k \leq f = b(a + c_1) + bc_k$. It can be shown that $ed_j = bc_k = fd_j$, for all $j = 1, 2, \ldots, k$. Also, $e + d_j = a + c_1 + bc_k = f + d_j$, for all $j = 1, 2, \ldots, k$.

Since L is weakly k-cancellative, e = f; thus, L is k-modular.

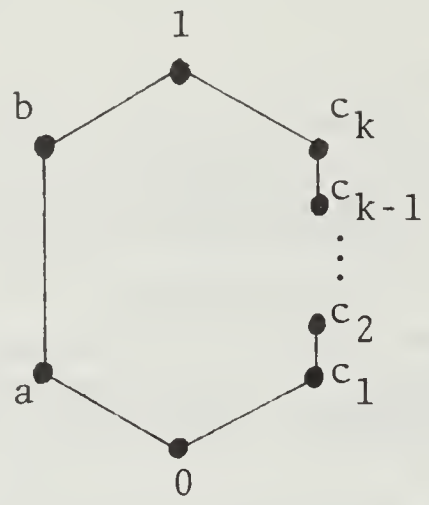

figure 1. N_{k+4}

(ii) implies (iii), immediately by the contrapositive.

(iii) implies (i). If a lattice L is not weakly k-cancellative, there exist elements a, b, c_1, ..., c_k such that $a \overset{<}{\neq} b$, $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \cdots \overset{<}{\neq} c_k$, $a + c_1 = b + c_1 = \ldots = a + c_k = b + c_k$ and $ac_1 = bc_1 = \ldots = ac_k = bc_k$. If $a \geq c_j$, then $b + c_j = a + c_j = a$ implies $b \leq a$, a contradiction. If $a \leq c_j \neq c_k$, then $c_j = a + c_j = a + c_{j+1} = c_{j+1}$, a contradiction. If $a \leq c_k$, then $a = ac_k = ac_1$ implies $a \leq c_1$, which again leads to a contradiction. Hence, a is non-comparable with the elements c_j of the chain. Similarly, b is non-comparable with the chain. The elements a, b, c_1, ..., c_k form a sublattice isomorphic to N_{k+4}.

Corollary 2. The principle of duality holds in the class of all k-modular lattices.

Corollary 3. A lattice L is 1-modular if and only if L is modular.

Corollary 4. If a lattice L is k-modular, then L is (k + 1)-modular.

We pause to remark that the preceding corollaries are necessary if we are to truly generalize the concept of modularity. Thus, for k = 1, k-modularity is equivalent to modularity; for k = 2, k-modularity reduces to 2-modularity [6]. We also note that the weakly k-cancellative property generalizes the weak cancellation principle of modular lattices, the M* lattices of Blumenthal [3]. It should also be noted that the converse of corollary 4 does not hold. A

finite example is N_{k+4} which is (k + 1)-modular since it does not contain $N_{(k+1)+4}$ but which is not k-modular. An infinite example is the lattice of linear subspaces of E^{k+1} (i.e., the lattice consisting of the null space, points, lines, planes, hyperplanes and E^{k+1}) which, again is (k + 1)-modular but not k-modular.

We now turn our attention to a generalization of distributivity:

Definition 3. A lattice L is k-cancellative if $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$, $a + c_1 = b + c_1 = \ldots = a + c_k = b + c_k$ and $ac_1 = bc_1 = \ldots = ac_k = bc_k$ imply a = b.

Definition 4. A lattice L is k-distributive if $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$ and $c_1 \nleq b$ imply $b(a + c_1) + bc_k = ab + bc_k$ or $c_2(a + c_1) + bc_k = c_1 + ac_2 + bc_k$ or $c_j(a + c_1) + bc_k = c_{j+1}(a + c_1) + bc_k$, for some j = 2, ..., k - 1.

Although the definition of k-cancellative lattices is the expected generalization of weakly k-cancellative, the definition of k-distributive lattices is somewhat unexpected. The definition of k-distributivity is not formed merely by the deletion of the comparability condition required for k-modularity. There is an additional condition, namely that $c_1 \nleq b$. This condition is necessitated by lattices containing sublattices isomorphic to L_{k+4}. Obviously L_{k+4} satisfies the k-cancellative property and thus warrants inclusion in the class of k-distributive lattices.

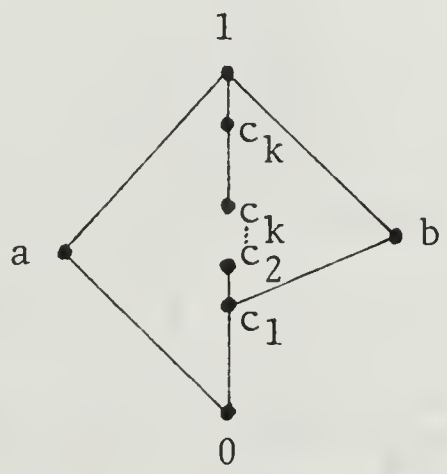

figure 2. L_{k+4}

It should be noted that although the addition of this condition in the definition of k-distributivity may not be esthetically pleasing, it is not in the least restrictive.

The standard results regarding distributive lattices generalize to analogous theorems of k-distributivity; the only consequence of this condition is that some proofs require consideration of two cases, rather than one.

Lemma 5. If a lattice L is k-cancellative, then L is weakly k-cancellative.

Lemma 6. If a lattice L is k-distributive, then L is k-modular.

Proof. Let $a \leq b$, $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$ in a distributive lattice L. If $c_1 \nleq b$, then, by k-distributivity, one of the desired equalities holds. If $c_1 \leq b$, then $a \leq b$ implies $a + c_1 \leq b$; also $c_1 \leq c_k$, so $c_1 \leq bc_k$. Hence, $b(a + c_1) + bc_k = a + c_1 + bc_k = a + bc_k$. Again, one of the desired equalities holds.

Theorem 7. The following are equivalent in a lattice L:
(i) L is k-cancellative.
(ii) L is k-distributive.
(iii) L does not contain a sublattice isomorphic to N_{k+4} or to M_{k+4}.

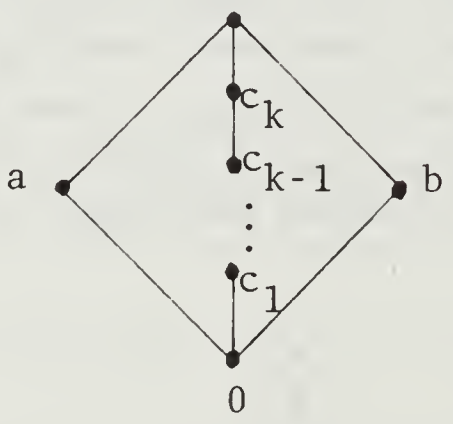

figure 3. M_{k+4}

Proof. (ii) implies (i). Let L be a k-distributive lattice with $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \ldots \overset{<}{\neq} c_k$, $a + c_1 = b + c_1 = \ldots = a + c_k = b + c_k$ and $ac_1 = bc_1 = \ldots = ac_k = bc_k$. If $c_1 \leq b$, then $b = b + c_1 = b + c_2$ implies $c_2 \leq b$ and hence $c_1 = bc_1 = bc_2 = c_2$, a contradiction. Thus $c_1 \nleq b$ and by k-distributivity one of the following must hold: $b(a + c_1) + bc_k = ab + bc_k$, $c_2(a + c_1) + bc_k = c_1 + ac_2 + bc_k$, or $c_j(a + c_1) + bc_k = c_{j+1}(a + c_1) + bc_k$ for some $j = 2, \ldots, k - 1$. If the second of these

equalities holds, then $c_2 = c_2(a + c_2) + bc_2 = c_2(a + c_1) + bc_k = c_1 + ac_2 + bc_k = c_1 + ac_1 + bc_1 = c_1$, a contradiction. Similarly, $c_j(a + c_1) + bc_k = c_{j+1}(a + c_1) + bc_k$ implies $c_j = c_{j+1}$, again a contradiction. Hence, the first equality must hold and $b = b(b + c_1) + bc_k = b(a + c_1) + bc_k = ab + bc_k = ab + ac_k \leq a$. Therefore $b \leq a$. By lemma 6, L is k-modular and hence, by theorem 1, L is weakly k-cancellative. Thus, $a = b$.

(i) implies (iii), immediately by the contrapositive.

(iii) implies (ii). If a lattice L is not k-distributive, there exist elements $a, b, c_1, \ldots, c_k$ such that $c_1 \overset{<}{\neq} c_2 \overset{<}{\neq} \cdots \overset{<}{\neq} c_k$, $c_1 \nleq b$, $e = ab + bc_k \overset{<}{\neq} f = b(a + c_1) + bc_k$, and $d_1 = c_1 + ac_2 + bc_k \overset{<}{\neq} d_2 = c_2(a + c_1) + bc_k \overset{<}{\neq} \cdots \overset{<}{\neq} d_k = c_k(a + c_1) + bc_k$. Let $g = a + bc_k$. It can be shown that $gd_j = bc_k = fd_j$, for all $j = 1, 2, \ldots, k$. Similarly, $g + d_j = a + c_1 + bc_k = f + d_j$, for all $j = 1, 2, \ldots, k$. If g and f are non-comparable, then $f, g, d_1, \ldots, d_k$ form an M_{k+4} sublattice. If g and f are comparable, but unequal, then $g, f, d_1, \ldots, d_k$ form an N_{k+4} sublattice. Lastly, if $g = f$, then $e, f, d_1, \ldots, d_k$ form an N_{k+4} sublattice.

Corollary 8. The principle of duality holds in the class of all k-distributive lattices.

Corollary 9. A lattice L is 1-distributive if and only if L is distributive.

Proof. Certainly, a distributive lattice is 1-distributive. Conversely, let L be 1-distributive. For elements a, b, c of L, if $c \nleq b$, then $b(a + c) = b(a + c) + bc = ab + bc$. If $c \leq b$, then by 1-modularity, $b(a + c) = b(a + c) + ba = ab + bc$.

Corollary 10. If a lattice L is k-distributive, then L is $(k + 1)$-distributive.

We remark that the converse of corollary 10 does not hold, both lattices N_{k+4} and M_{k+4} are $(k + 1)$-distributive yet not k-distributive. Also, the converse of lemma 6 does not hold; M_{k+4} is a k-modular, non-k-distributive lattice. Among the remaining questions are those which seek conditions under which the converses of corollary 10 and lemma 6 will hold. Further, it has been shown [6] that, for $k = 2$,

there is a subclass of 2-modular lattices which admits a 2-norm such that every 2-normed lattice is a 2-metric space in the sense of [4]. A natural question, then, is the existence of a subclass of k-modular lattices which admits a k-norm such that every k-normed lattice is k-metrizable.

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ABSTRACTS OF PAPERS PRESENTED AT THE
1977 JOINT MEETING
ILLINOIS STATE ACADEMY OF SCIENCE
MISSOURI ACADEMY OF SCIENCE

COLLEGIATE DIVISION

BIOLOGICAL SCIENCES

INHIBITION OF ANAPHYLACTIC REACTIONS AND REDUCTION OF HUMORAL ANTIBODY TITERS BY AN ANTI-COMPLEX SERUM TO BSA-ANTI-BSA PRECIPITIN, D. J. Stansfield and J. M. Downs, Sponsor - C. M. Hampton, Jefferson College, Hillsboro, MO 63050. Sera from rabbits with high BSA titers displaying anaphylaxis were precipitated out invitro to form a BSA-anti-BSA complex. This complex was injected into a second group of rabbits to produce an anti-complex sera for the inhibition of the allergic anaphylactic reaction. Inhibition of anaphylaxis was demonstrated invivo in the first group of rabbits eight hours after receiving an intravenous injection of the anti-complex sera. Invitro tests showed a significant reduction of titer in the sera of anaphylactic rabbits. The mechanism of this new approach and it's application to specific allergies may produce a major breakthrough in the control of hypersensitivity.

THE EFFECTS OF CHORIONIC GONADOTROPIN, TESTOSTERONE, PROPIONATE, SESAME OIL, PEANUT OIL, MINERAL OIL, COD LIVER OIL, AND CASTOR OIL ON YOUNG CHICKENS. Kevin M. McCartney, Susanne C. Webster, and JoAnne K. Solliday, Culver-Stockton College, Canton, MO 63435. The androgenic effects of testosterone carrier on young chickens were analyzed in three separate experiments. In the first study, testosterone propionate and human chorionic gonadotropin were used with appropriate controls to compare the effects of these hormones on comb growth, body weight, and gonad development. The second experiment compared the appearance of the comb tissue when chickens were injected daily with testosterone or with sesame oil alone. The third experiment compared the effects of various oil carriers on comb development and body weight. It was found that sesame oil and peanut oil have definite androgenic effects on the chicks.

COMPARISON OF THE STANDARD AND MODIFIED KIRBY-BAUER METHODS IN TESTING ENTEROCOCCI WITH GENTAMICIN, Joan M. Williams, Stephens College, Columbia, Missouri, 65201. Susceptibility of enterococci to gentamicin as determined by the standard Kirby-Bauer, modified Kirby-Bauer, and the Minimal Inhibitory (MIC) tube dilution test was compared. Results of the standard Kirby-Bauer test showed enterococci to be resistant to gentamicin. On the other hand, the modified test demonstrated sensitivity to gentamicin. When susceptibility was determined using the MIC dilution test organisms were found to be resistant. This result establishes the modified Kirby-Bauer test as unacceptable for testing the susceptibility of enterococci to gentamicin.

EFFECTS OF NEAR-ULTRAVIOLET LIGHT ON HEAD REGENERATION IN PLANARIA, E. J. Horton, University of Missouri, Columbia, 65201. Light-adapted planaria of the species Dugesia tigrina show normal blastema formation after head transection but a significant number of deformed eyespots were noted when the regenerates were treated with 1.0×10^{-3}M H_2O_2 or 5.6×10^5 J/m^2 dosages of N-UV during the regeneration period. These same deformed animals show delays in normal negative phototactic behavior to 508 nm light; the largest number of deformities were when the animals were treated 36 hours after transection. Repeated regeneration of deformed head regions shows possible permanent damage in capacity to regenerate normally pigmented eyes. This indicates possible damage to enzyme templates or gene products that are critical to eye formation.----Supported by NSF-SOS #76-08039.

THE EFFECTIVENESS OF IMPLANTATION OF EXOGENOUS LACTOBACILLI INTO THE INDIGENOUS COLONIC MICROFLORA, Holly Maria Bright, Stephens College, Columbia, Missouri, 65201. The effectiveness of implanting two species of lactobacilli, L. acidophilus and L. bulgaricus, into the indigenous colonic microflora of patients with malignant disease receiving abdominal radiation therapy was determined. Subjects were given lactobacilli feeding four times a day for thirty days and weekly fecal specimens were analyzed for bacterial populations. No lactobacilli were found above 10^6 org/gm (wet weight). No significant quantitative or qualitative changes were observed in the indigenous colonic microflora. However, when fecal specimens were diarrheal, anaerobic organisms were observed in significantly lower numbers.

SECOND DISSOCIATION CONSTANT OF GLYCINE IN 50 MASS % DIGLYME-WATER AT FIVE DIFFERENT TEMPERATURES, James Moeller and Charles Tillman, Jr., Department of Chemistry, Drury College, Springfield, Missouri 65802. The second thermodynamic dissociation constant of glycine at five temperatures (5°, 15°, 25°, 35° and 45°C) in 50 mass % diglyme-water mixed solvent have been determined from precise emf measurements with hydrogen-silver bromide electrodes in cells without liquid junction. The second acidic dissociation constant (K_2) for the process $G^{\pm} \rightleftharpoons H^+ + G^-$ over the temperature range studied will be expressed by means of an equation of the type $pK_2 = A + B/T + CT$, from which the standard thermodynamic quantities ($\Delta G°$, $\Delta H°$, $\Delta S°$, and $\Delta C_p°$) will be calculated. These results will be compared with those determined in other mixed solvent media, such as methanol-water, monoglyme-water, and tetrahydrofuran-water systems.

IMPLICIT NUMERICAL ANALYSIS FOR KINETIC EQUATIONS, Dale Medley, University of Missouri, Columbia, 65201. Systems of differential equations which arise from the conversion to its matnematical interpretation of a physical model for a reaction mechanism may often be accurately solved through multi-step implicit numerical techniques of integration. Comparing the application of a standard method, a modified form of fourth order Runge-Kutta, and a new implicit algorithm based on the work of C.W.Gear to the particular problems of shock tube kinetic studies illustrates the advantages of both routines. In these experiments, equilibrium constants for the component reactions involved differ in each step as the temperature varies, a factor which increases the complexity of each integration cycle. Thus, while the Gear method uses innovations such as variable order to enable the step size to be larger, the Runge-Kutta benefits in efficiency from its more simple format.

SPECTROSCOPIC INVESTIGATION OF MULTIPLE ELECTRON DONOR-ACCEPTOR COMPLEXES OF TETRACYANOETHYLENE WITH NAPHTHALENE, Matt Harthcock and C. C. Thompson Southwest Missouri State University, Springfield, 65802.

Molecular complexes of tetracyanoethylene (TCNE) with naphthalene, dissolved in hexane, were studied by optical absorption methods. Association constants and molar absorptivities were computed for both 1:1 and 2:1 naphthalene-TCNE complexes. The association constants and molar absorptivities for the 1:1 and 2:1 complexes were calculated using Scatchard plots, and a computer search program. The association constant for the 1:1 complex was found to be 8.5 $l\text{-mole}^{-1}$, whereas the corresponding value for the 2:1 species was 0.2 $l\text{-mole}^{-1}$. Molar absorptivities at 530 nm were 840 and 2600 $l\text{-mole}^{-1}\ cm^{-1}$ for the 1:1 and 2:1 complexes, respectively. These results substantiate previous suggestions of multiple equilbria as an explanation for anomalous behavior observed in molecular complex systems.

SYNTHESIS OF PHOSPHINOUS ACID AND PHOSPHONOUS ACID ESTERS AND DETERMINATION OF THE σ-BASICITY/π-ACIDITY RATIO FOR THESE LIGANDS IN $LNi(CO)_3$ COMPLEXES, Melanie P. May and George M. Bodner, Stephens College, Columbia, 65201. Previous work has suggested that the ^{13}C NMR carbonyl chemical shift in $LNi(CO)_3$ complexes of P, As and Sb ligands can be interpreted in terms of the ratio of the σ-basicity of the ligand to its π-acidity. We have synthesized ligands of the type: $Ph_2P(OR)$ and $PhP(OR)_2$ {R = Me, Et, Pr, iPr, Bu, Ph} as well as their $LNi(CO)_3$ complexes in order to investigate additivity effects upon the σ-donor/π-acceptor character of P ligands. Data obtained for these derivatives can be correlated with and predicted on the basis of the study of corresponding $Ph_3PNi(CO)_3$ and $(RO)_3P$-$Ni(CO)_3$ derivatives.

DETERMINATION OF THE HEAT OF FORMATION FOR THE DECAVANADATE SPECIES IN WATER, Michael Seneff, University of Missouri at Columbia, 65201. Objective is to determine the heat of formation of the unprotonated decavanadate species, $V_{10}O_{28}^{6-}$. Method involves use of a Tronac calorimeter in monitoring the conversion of orthovanadate to the desired species. The reaction is pH controlled and may be written:

$$10\,VO_4^{3-} + 24\,H^+ \longrightarrow V_{10}O_{28}^{6-} + 12\,H_2O$$

heat given off by this reaction is measured using the calorimeter, and data combined with existing values of ΔH_f° for VO_4^{3-} to give the desired ΔH_f° of $V_{10}O_{28}^{6-}$

NATURAL AREA SURVEYS: A MULTI-DISCIPLINARY APPROACH, Alice Walters, Eric Peterson, and Tom Hinckley, University of Missouri, Columbia. In a project funded by the National Science Foundation seven students conducted a natural area study of eight Missouri State Parks during the summer of 1976. The objectives were to 1) locate areas in the Parks which could be included in the Missouri Natural Area System and 2) to work with students of various disciplines as a single research team. Our team consisted of students in forestry, wildlife, anthropology, geology and economics. Natural studies included vegetational and geological surveys. We also conducted benefits to cost analysis and demographic analysis. At the end of the study 10 natural areas were selected from the Parks. Nine of these areas had benefits to cost ratios favoring natural area preservation. The user attitude survey indicated a willingness on the part of park users to preserve natural areas.

METABOLISM OF THE TUMOR PROMOTER TPA USING HPLC, Michael R. Lieber, University of Missouri-Columbia, 65201. The initiation-promotion scheme of chemical carcinogenesis is a method of experimentally inducing malignant tumors. In its simplest form, the method consists of administering a sub-threshold dose of carcinogen followed by a non-carcinogenic compound, the promoter. By themselves, the two applications are not capable of inducing cancer. But together, they yield high frequencies of malignancy. The metabolism of the second of the two applied compounds, the promoter, is important to the study of its mechanism of action. In this investigation, the metabolism of the tumor promoter, 12-O-tetradecanoyl-phorbol-13-acetate (TPA), was examined using high pressure liquid chromatography of liver and skin tissue extracts from mice. A tritiated form of the TPA was administered to the mice both topically and intraperitoneally. In vitro metabolism was also studied using the cytoplasmic and microsomal cell fractions from mouse liver.

CHEMISTRY

ELECTROPHILIC CLEAVAGE OF MOLYBDENUM-CARBON SIGMA BONDS. M. Dattilo and K.W. Barnett, Department of Chemistry, University of Missouri-St. Louis, St. Louis, Mo. 63121.

Halogen and mercuric halide cleavage reactions of the molybdenum-carbon sigma bond in trans-$\eta^5C_5H_5Mo(CO)_2LR$ complexes [L= $P(C_6H_5)_3$, P(n-butyl$_3$), P(p-tolyl)$_3$; R=CH_3, $COCH_3$] have been investigated. Reactions of bromine and iodine with the methyl or acetyl complexes yield predominantly trans halide (1). Cleavage by mercuric halides yield exclusively cis halides (2) or trans mercury bonded halide (3). Stereochemical assignments based upon infrared, ^{1}HNMR, and ^{13}CNMR spectral data and possible mechanisms of these reactions will be discussed.

$$\text{trans-CpMo(CO)}_2\text{LR} + X_2 \longrightarrow \text{CpMo(CO)}_2\text{LX} + \text{RX} \quad (1)$$

$$\text{trans-CpMo(CO)}_2\text{LCH}_3 + HgX_2 \longrightarrow \text{cis-CpMo(CO)}_2\text{LX} + C \quad (2)$$

$$\text{trans-CpMo(CO)}_2\text{LCOCH}_3 + HgX_2 \longrightarrow \text{trans-CpMo(CO)}_2\text{LHgX} \quad (3)$$

$MgSO_4$-CATALYZED THERMOLYSIS OF 1,3-DIOXAN-2-ONES - A NEW SYNTHESIS OF HOMOALLYLIC ALCOHOLS, Peter Gannett and Scott Searles, Jr., University of Missouri-Columbia, 65201. A possible new synthesis of homoallylic alcohols by the $MgSO_4$-catalyzed thermolysis of cyclic carbonate esters of 1,3-diols has been investigated. In the present work, the method has been successfully applied to the synthesis of 3-buten-1-ol and 2-ethyl-3-hexen-1-ol from the cyclic carbonate esters of 1,3-butanediol and 2-ethyl-1,3-hexanediol in yields of 50% and 61%, respectively. The isomeric allylic alcohols are formed concomitantly, but are effectively removed by treatment with MnO_2. The method seems to offer an easier and more economical route to homoallylic alcohols than other presently available ones.

SOLVENT EFFECTS ON THE DISSOCIATION CONSTANT OF M-NITROANILINIUM ION IN THE TETRAHYDROFURAN-WATER MIXED SOLVENT SYSTEM AT 25°C, Steve Faszholz and Ken Buechtner, Department of Chemistry, Drury College, Springfield, Missouri 65802. The dissociation constant of m-nitroanilinium ion has been determined spectrophotometrically in tetrahydrofuran-water mixtures of 0, 10, 30 and 50 mass % at 25°C. The data for the pK_a of the m-nitroanilinium ion in water at 25°C was found to be 7.463, which is in good agreement with the literature value of 7.465. The variation in the pK_a value with an increase in the tetrahydrofuran content will be discussed, and interpreted as it pertains to an increase or decrease in the acidity of the m-nitroanilinium ion in the mixed solvent, as opposed to its behavior in water. The acid-base properties, as well as the structure of the mixed solvent, will be interpreted in terms of an electrostatic model.

POTENTIOMETRIC MEASUREMENTS OF THE EFFECTS OF SALTS ON STRONG ACIDS; THE SYSTEM HBR + $(C_2H_5)_4NBR$ + H_2O AT 25°C, James Moeller and Ron Snelling, Department of Chemistry, Drury College, Springfield, MO 65802. Measurements were made on the system HBr + $(C_2H_5)_4NBr$ + H_2O using an e.m.f. cell, without liquid junction, of the type

Pt, H_2(g,1 atm) | HBr(m_1)+$(C_2H_5)_4NBr(m_2)$ | AgBr, Ag

in the total molality ranges of m, where $m = m_1 + m_2$, equal to 0.1, 0.25, 0.5 and 1.0 mole kg^{-1}. Harned's Rule has been tested for the variation of the activity coefficients in these mixtures of electrolytes, and the data have been examined by means of both linear and non-linear curve-fitting techniques. The results are discussed at low dilution (0.1 mole kg^{-1}) in terms of the Bronsted-Guggenheim specific interaction coefficient, $^{B}(C_2H_5)_4N^+,Br^-$, as well as being interpreted in terms of Pitzer's equation for the total molality range under investigation.

THERMODYNAMIC STUDY OF HCL IN 10, 30, AND 50 MASS % DIGLYME-WATER AT 25°C, Ken Buechtner and Ron Snelling, Department of Chemistry, Drury College, Springfield, Missouri 65802. Electromotive-force measurements of cells of the type Pt;H_2(g,1 atm) HCl(m) in Diglyme + H_2O) AgBr,Ag at 25°C were used to derive (a) the standard e.m.f. of the cell in water + 10, + 30, and + 50 mass % diglyme, (b) the mean activity coefficient of HCl, (c) the Gibbs free energy for the transfer of HCl from the standard state in water to the standard state in each of the above mixed solvent media, and (d) the medium effects. The molality m of the acid ranged from 0.01 to 0.0 mole kg^{-1}. Vapor pressures and densities for the binary solvent mixtures were measured at 25°C. The standard e.m.f. was determined by means of an extrapolation method, using the extended terms of the Debye-Hückel theory. The results will be discussed in terms of the preferential solvation of the ions.

Physical Sciences

A DEPENDABLE, LOW-COST NITROGEN LASER USED IN LIDAR STUDIES. K. McGinnis. (University of MO-Rolla, Rolla, MO 65401). A Nitrogen laser, lasing at 3,371 Å having a pulse width under 20 nanoseconds was constructed using 1 5/8" plastic drain pipe, copper sheet, mylar insulation, wax paper, and 1" G-10 epoxy board. The laser is similar in design to James G. Small's (M.I.T.) Nitrogen laser. Modifications keeping the copper plates of the capacitors from bouncing during operation increased the durability of the laser. When used as the signal source for a lidar the laser was mounted parallel to a 10" Celestron telescope. Data could then be taken on clouds by following them in the field of view of the telescope.

VIBRATIONAL ANALYSIS OF A MEMBRANE USING HOLOGRAPHIC INTERFEROMETRY. D. H. Perkins and D. J. Ruprecht (University of Mo-Rolla, Rolla, Mo. 65401). Holographic interferometry has widespread applications in the study of mechanical vibrations. This paper describes the mathematical analysis of a vibrating edge-clamped membrane and the holographic techniques used to display the predicted patterns. This type of work has potential for further development in other applications such as plate vibrations.

AN INVESTIGATION OF ATMOSPHERIC VISIBILITY, Howard L. Brooks, William Jewell College. Report on the development of an experimental detection system and comparison of collected data with theoretical expectations.

INTENSITY MEASUREMENTS OF DIFFRACTED SOUND WAVES, Larry Long, Northwest Missouri State University, Maryville, Missouri 64468. Using an acoustical box, speaker, microphone and a phase-sensitive amplifier (lock-in) the position of the wave can be found by moving the microphone through a phase of 360^0 from the initial wave. The intensity can be determined by shifting the phase on the lock-in till a maximum meter reading is found, from this information the relative intensity can be found for each wave.

NUMERICAL METHODS APPLIED TO ATMOSPHERIC PARTICLE SAMPLING DATA, Steve Garland, Northwest Missouri State University, Maryville, Mo. 64468. This investigation involves the use of data gathered from a high volume cascade impactor on a high volume air sampler. To determine the effects of various weather parameters and the calendar date on the amount of particulate matter gathered and the composition of the particulate, a preliminary investigation was conducted in 1975. Since then the investigation has been expanded to include numerical analysis of the data. The study was confined to Maryville, Missouri.

COMPUTER SIMULATED RENDEVOUS WITH COMET ENKE, Walter Lounsbery, UMR, Rolla, 65401. On December 6, 1980 comet Enke reaches apohelion, One proposal under project Helios was to outfit a satellite with appropriate experiments and perform a rendevous or slow fly-by of Enke. A relatively short program was written and de-bugged by the author which interactively explores various launch dates and trajectories for this mission. Special features of the program are mid-course correction capability, non-zero beta launch angle, and capability for hyperbollc and elliptic orbits. The end result was a practical, precise tool to find good 'windows' for the mission, an educational tool to illustrate orbit mechanics, and an interesting graphics game.

A DESIGN APPROACH TO WINDMILL THEORY. Walter Lounsberry (University of Missouri-Rolla) There is at present a confusing literature of windmills, presenting diverse theories, performance parameters, and formuli that barely apply to design needs. By applying a simple but far reaching modification of the vortex theory to windmills, a few basic formuli eveolve. These formuli indicate practical performance parameters, a means of optimizing windmill design, and a general optimized windmill equation, which is a completely new development. The theory is evolved into actual design methods, which are embodied in a library of designer-interactive computer programs.

ILLINOIS COLLEGIATE CHEMISTRY

A TURBIDIMETRIC METHOD FOR DETERMINING THE SURFACE CHARGE IN PAPER SAMPLES, John Hoots and Clarence Josefson, Millikin University, Decatur,Illinois, 62522, and Donald Halabisky,A.E.Staley Research Center, Decatur, Illinois, 62522.
A turbidimetric method was developed for determining the endpoint in a titration of paper samples with cationic and anionic polymers. Comparison was made with an existing method using visual color endpoint detection. The turbidimetric method gave better precision for a larger variety of paper samples.

EDTA-TITRATION TECHNIQUES AS A MEANS FOR DETERMINING NICKEL CONTENT IN IRON METEORITES, C.Duane Sell, William E. Broderick, August Ochabauer, Paul P. Sipiera, Harper College, Palatine, IL 60067. Nickel analysis by precipitation with Dimethylglyoxime has been the standard procedure for recognition and classification of iron meteorites. However inherent errors in solution transfer can severely affect the reliability of this procedure. In the present study, spectrophotometric and EDTA-titration procedures were employed for nickel analysis fo a specimen of the Canyon Diablo iron meteorite in an effort to establish a more precise method of analysis. The EDTA-titration proved to be the better technique based on its simplified procedure, precision, and small error factor involved. This method will be employed in future studies as our means of determining nickel content.

LANTHANIDE COMPLEXES OF 2-THIOPYRIDINE N-OXIDE, Chet A. Frank and Douglas X. West, Illinois State University, Normal,61761. Lanthanide metal complexes of 2-thiopyridine N-oxide have been isolated as crystalline powders from aqueous solution. The derived compounds have been characterized by partial elemental analysis and infrared spectra. The spectral data derived for these complexes will be compared to the reported information for the transition metal ion complexes. Results of molar conductivity and thermoanalytical measurements will be reported in addition to the details and interpretation of electronic spectra.

METAL ION COMPLEXES OF 2-ALKYLAMINOPICOLINE N-OXIDES, Timothy P. Henning and Douglas X. West, Illinois State University, Normal, IL, 61761. The title ligands have been prepared by aminolysis of 2-picoylchloride N-oxide. Metal ion complexes have been isolated from ethanolic solutions containing different ligand to metal ion mole ratios. Characterization of the derived complexes has been accomplished by partial elemental analysis, infrared spectra, molar conductivites, and solid state and solution electronic spectra. Ligand field parameters derived from experimental data will be included.

METAL ION COMPLEXES OF THE CONJUGATE BASE OF 3,4,5-TRIMETHYL-1-HYDROXYPYRAZOLE 2-OXIDE, Mary Ann Vanek and Douglas X. West, Illinois State University, Normal, IL, 61761.
Transition metal ion and lanthanide complexes of the title ligand have been isolated from aqueous solution. The derived complexes have been characterized by partial elemental analysis, infrared and electronic spectra, molar conductivities and thermal analytical techniques. Of particular interest is a comparison of these complexes with the related phenyl substituted ligand's complexes reported on recently with respect to the nature of the coordination sphere.

SYNTHESIS OF DIELS-ALDER ADDUCTS OF SUBSTITUTED CINNAMIC ACIDS AND 2,3-DIMETHYLBUTADIENE. Leland Harris, David Lymberopoulos and Jorge Castanos, Knox College, Galesburg, Illinois 61401.
Several new substituted cyclohexenes have been prepared by the cycloaddition of ring substituted cinnamic acids and 2,3-dimethylbutadiene. Unavailable ring substituted acids were synthesized using the Sommelet reaction and the Perkin Condensation. Diels-Alder adducts were prepared by reaction in xylene solvent in a pressure vessel at 180°C for 15 hours. Mono- and multi-substituted aromatic ring substituted methyl- and methoxy-cinnamic acids were used as the dienophiles. The structures of the adducts were verified by carbon, hydrogen analyses, infrared and ^{1}H NMR spectra.

COAL STUDIES WITH SODIUM METAL AND CARBONATION REACTIONS IN TETRAHYDROFURAN -SOLUBILITY AND STRUCTURE STUDIES, John Harwood and Robert Duty, Illinois State University, Normal, IL 61761.
The solvation of bituminous coal in aqueous solutions was studied after reacting the coal in anhydrous tetrahydrofuran (THF). The effects of carbonation reactions with CO_2 gas on solubility and the uptake of sodium by the residual coals was studied. Flame emission spectrophotmetric analyses were made of the coal after acid digestion bomb preparation. Mesh sizes of coal samples varied from 80/100 to 400plus. Results were:
% solubility of unreacted coal/% Na: 7.54-10.2%/0-0.10%.
%solubility of reduced coal/%Na:2.18-8.31% /2.00-10.3%.
%solubility of carbonated coal/% Na: 3.37-10.4%/2.00-7.6%.
Decreasing mesh sizes in these ranges does not significantly affect solubility. Carbonation reduces solubility of coal in THF, however, it increases solubility in water.

EFFECT OF STEROIDAL GLYCOALKALOIDS ON CELL MEMBRANES AND ON NITRATE REDUCTASE ACTIVITY,Mark A. Johnson and Elaine Z. Herzog,University of Illinois Chicago Circle, Chicago, 60680. α-solamarine,β-solamarine and solamargine were isolated from Solanum Dulcamara L., identified and quantified by a method sensitive to 1γ of alkaloid. In an in vivo assay of nitrate reductase in the leaves of S. Sulcamara 5mM aqueous solution of alkaloids increased enzyme activity as much as 80% over controls. There was at the same time leakage of cellular material. This suggests the possibility that the steroidal glycoalkaloids increase cell membrane permeability to nitrate and nitrite ions.

CHANGES IN BRAIN AND TESTES PROTEIN SYNTHESIS IN RATS OF VARIOUS AGES, Richard Ekstrom and Arlan Richardson, Illinois State University, Normal, 61761. Cell-free protein synthesis by the post-mitochondrial supernatant in whole brain and testes was determined in Fischer rats obtained from the NIH animal colony. Cell-free protein synthesis in these tissues was found to be linear for the first 10 min of incubation and plateaued after 30 min of incubation. Using optimum conditions, the protein synthetic activity of the post-mitochondrial supernatant obtained from brain and testes was determined in rats ranging in age from three to twenty-eight months. A decrease in cell-free protein synthesis was observed with increasing age.

CHANGES IN PROTEIN,DNA, AND RNA CONCENTRATIONS IN RAT TISSUES WITH AGE, John W. Spicer, Diane Burgess and Arlan Richardson, Illinois State University, Normal, 61761. The protein, DNA, and RNA concentration of brain, testes and liver were determined in three to twenty-eight month old Fischer rats obtained from the NIH animal colony. The protein content of the tissues was determined by the Lowry method, DNA content bu the indole method and RNA content by sodium hydroxide hydrolysis. The macromolecular content of the brain was less than the macromolecular content of either testes or liver. In all cases the concentration of DNA,RNA and protein reached a maximum in the year old rats and remained constant.

AGRICULTURE

LOBLOLLY PINE RELEASE AND EFFICACY TESTS WITH SELECTED HERBICIDES, Gerald Gaffney, Southern Illinois University, Carbondale 62901, and John W. Reeves, Western Illinois University, Macomb 61455. Conventional formulation of phenoxy compounds were compared with an inverted emulsion system and a stearic acid additive on loblolly pine. Observations were made on efficacy, tree injury, and tree release. The data suggested that all chemical treatments produced a negative growth response when compared with mowed and control plots. The data further suggested that stearic acid used as a drift inhibitor produced less tree damage than invert emulsion or conventional formulations. The damaging results of chemical application on the trees appeared to over-ride the herbicidal effect on growth response.

A PHOTOGRAPHIC STUDY OF WHITE OAK TREE RESPONSE TO ENVIRONMENTAL HAZARDS, P.S. Szopa, E.A. McGinnes, Jr., and A.L. Shigo, University of Missouri, Columbia, MO 65201. Several white oak trees were dissected in study of tree response to injury to and interruption of the cambial tissue along the bole. Photographs demonstrate healing growth patterns around fire damage and dead limb stubs along with a discussion of other hazards such as lightning and mechanical injury. When cambial tissue on the bole is destroyed (i.e., fire damage), or interrupted (i.e., dead limb), radial growth at that point stops, and does not resume until the adjacent cambial tissue has healed over the wound. A tree does not replace damaged tissue, but covers it with new growth.

THE MORPHOLOGY AND GEOGRAPHIC DISTRIBUTION OF THE MYRISTICACEAE, Joseph Armstrong, University of Missouri, Columbia, MO 65201. The Myristicaceae, a small to medium-sized family with a pantropical distribution, is a member of the woody Ranales. Each of the fifteen genera in this family is restricted to one of the three major tropical areas. Morphological data suggest that the least specialized forms of the staminate flowers, the leaf venation patterns, and the pollen exine structures are found in South American genera. Based on this evidence, the most likely center of origin and distribution for the family is South America. Lacking any means of long distance dispersals, it is unlikely that the distribution of the family is a recent event. The fragmentation of the former supercontinent Gondwanaland is a possible mechanism for the dispersal of these plants.

GEOGRAPHIC VARIATION OF WHITE ASH, F.H. Kung and C.F. Bey, Southern Illinois University, Carbondale, IL 62901. White ash (Fraxinus americana L.) is an important hardwood species in eastern United States and southern Canada. Seed were collected from 55 geographic areas throughout its native range. Early nursery results indicated that white ash from southern sources tended to be taller and hold their leaves longer in the fall than trees from northern sources. The taller trees also tended to be greener and have a wider leaf angle. Trees from this test have been outplanted at 23 locations throughout eastern United States for further study.

ANATOMICAL RESPONSE AND RECOVERY OF TWIGS OF JUGLANS NIGRA FOLLOWING OVIPOSITION INJURY INFLICTED BY THE TWO-SPOTTED TREEHOPPER, ENCHENOPA BINOTATA, J.E. Armstrong, W.H. Kearby, and E.A. McGinnes, Jr., University of Missouri, Columbia, MO 65201. 1, 2, and 3 year old ovipositow wounds on twigs of J. nigra were examined for anatomical responses and injury recovery using both light and scanning electron microscopy. The treehopper's ovipositor makes a longitudinal slit in the bark of first year twigs, which curves tangentially splitting the tissues along the cambial layer. Following oviposition in August to early October, there is some proliferation of cork and parenchyma cells surrounding the wound. Following egg hatching and nymph emergence in May, extensive callous formation and cambial activity reestablishes the continuity of the vascular cambium. Third-year growth produces normal secondary xylem; externally the injury scar remains.

SOME ANATOMICAL OBSERVATIONS ON THE INFLUENCE OF MORPHACTINS ON WOOD FORMATION IN CARPINUS BETULUS L., J.E. Phelps, E.A. McGinnes, Jr., M. Smolinski, M. Saniewski, and J. Pieniazek, Univ. of Missouri, Columbia 65201, Lódź Univ., Lódź and Institute of Pomology, Skierniewice, Poland. Morphactins have been shown to influence unique kinds of cellular differentiation in some woody species. The present study was done to examine the influence of morphactin on xylem differentiation in C. betulus L. Two shoots were treated with morphactin IT 3456 on June 1, 1975. The morphactin was applied at a concentration of 0.5% in lanolin paste and as a ring around the shoots. Following application of morphactin, cellular differentiation was altered in that vessels were considerably smaller on transverse section than normal. It also appeared that all cell types were disorientated off their longitudinal axis after morphactins were applied.

AN ANALYSIS OF THE RETENTION AND CONDITION OF AGRICULTURAL CONSERVATION PROGRAM CONIFER PLANTINGS IN MISSOURI, W. B. Kurtz and R. J. Alig, University of Missouri-Columbia, Columbia 65201. Fifty-two tracts that had been planted to conifers from 8 to 17 years earlier under Agricultural Conservation Program cost-sharing were inspected to determine their forest stand condition, retention rate and associated characteristics. Information gathered included: acreage planted, original applicant and current owner characterisitcs, site characteristics, forest stand characteristics and evidence of silvicultural activity. Six tracts experienced some degree of planted acreage non-retention and 20 tracts were subjectively evaluated as being in poor condition. It appears that degree of retention and stand condition of a tract is related to the extent of site preparation, amount of silvicultural activity on the tract and, possibly to the amount of original acreage planted.

AN ECONOMIC ANALYSIS OF SUBSIDIES FOR SMALL WOODLOT MANAGEMENT IN SOUTHERN MISSOURI, T. K. Foutch and W. B. Kurtz, University of Missouri-Columbia, Columbia, 65201. The effect of various cost-sharing rates for planting and thinning on governmental direct program costs and on private forestry investment returns at different stumpage prices was examined for typical woodlot operations. A minimum threshold for investment feasibility was set at a 5% internal rate of return and a positive present net worth discounted at 7%. The threshold level for pine woodlots was 100% cost-sharing at a stumpage price of $12.50/MBF (1,000 bd. ft.) or 50% cost-sharing at $22.50/MBF. For oak woodlots the threshold was attained at a price of $15.00/MBF with 100% cost-sharing for thinning or 75% cost-sharing for thinning at $25.00/MBF. Governmental direct program costs were less than the market value of the timber produced from pine woodlots at all prices. Only with a cost-share of 25% for oak woodlot thinning did the market value of wood produced exceed direct program costs.

AVAILABILITY OF FOREST AND ASSOCIATED LAND RESOURCES IN ILLINOIS, John H. Burde, Southern Illinois University, Carbondale 62901. Land use decisions require good input-data, but most available for Illinois is outdated and/or inaccurate. Past inventories neglected landowner objectives causing an overestimation of actual availability, and associated lands causing an underestimation of lands that should be in forest production. Various sources of secondary data were examined to update current estimates. Landowner objectives were added to the calculations. The results showed that of the 8 million acres of forest and associated lands in Illinois, only 900,000 acres are available for timber production.

NUT PRODUCTION AND LEAF AREA OF RELEASED AND FERTILIZED BLACK WALNUT (Juglans nigra) IN SOUTHWEST MISSOURI, Phillip E. Graf and H. E. Garrett, School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia, 65201. A combination of stand condition and foliar fertilization significantly effected nut production and leaf surface area during the first year of treatment. Natural, 37-year-old black walnut trees located near Stockton, Missouri were released on two separate sites and given five foliar applications of NZN (Allied Chemical Co. - 22%N, 5.5% Zn) during the summer of 1976. Analysis indicated that foliar fertilization with NZN resulted in a significant increase in nut production. The interaction effects of released with NZN had the greatest response. The interaction between stand condition and NZN for leaf area was significant at the 0.10 level. The non-released and NZN combination showed the greatest leaf area.

SELF-CONTROL OF GROWTH IN H. MAYDIS, H. A. Requejo and A. L. Karr, University of Missouri, Columbia, MO 65201. The growth of H. maydis, races O and T, is inhibited by the host-specific toxins produced by H. maydis, race T. Race T is less sensitive to its own toxins than susceptible corn lines but is more sensitive than resistant corn lines. Toxin IV which is only weakly toxic to susceptible corn lines is very active in inhibiting fungal growth. Race O and T toxins are equally potent inhibitors of fungal growth. The effect of the toxins on growth of race T differs in that the organism can overcome race T toxin inhibition (but not race O toxin inhibition) when the cultures are illuminated.

THE EFFECT OF THE H. MAYDIS, RACE T, TOXINS ON THE NON-ELECTROLYTE PERMEABILITY OF CORN CELL MEMBRANES. L. Hsu and A. L. Karr, University of Missouri, Columbia, MO 65201. The purpose of this study is to determine what changes take place in host cell membrane structure early in the process of disease development. The values for hydraulic conductivity (L_p), reflection coefficients ( ), and solute permeability coefficients ( ) were measured in root cells from Tcms and cmf lines of corn both before and after treatment with the host-specific toxin produced by H. maydis, race T. Treatment with the toxin caused a decrease in restriction of water flow across the plasma membrane in cells from Tcms lines of corn (susceptible) but not from cmf corn lines (resistant).

ALPHA-GALACTOSIDASE PRODUCTION IN CULTURES OF H. SACCHARI, A. Darus and A. L. Karr, University of Missouri, Columbia, MO 65201. Helminthosporium sacchari (causal agent of eyespot disease of sugarcane) produces an α-galactosidase when grown in culture with melibiose as the carbon source. The enzyme appears in the medium at a time when fungal dry weight increase has nearly ceased. The enzyme has a molecular weight of greater than 250,000 daltons but is not precipitated with 95% (of saturation) ammonium sulfate. The enzyme gives none of the classical tests for proteins but does react with the anthrone reagent. Hence, it is probably a complex glycoprotein. The enzyme is specific for the α-anomeric configuration of galactose and appears to be the only hydrolase secreted by the organism under these conditions.

INFLUENCE OF SEVERAL AGRONOMIC PARAMETERS ON THE ISOLATION OF CERCOSPORA KIKUCHII FROM SOYBEAN SEED, Yishan Lin, George Kapusta, and A. J. Pappelis, Southern Illinois University - Carbondale, 62901. The influence of indeterminate soybean (Glycine max (L.) Merrill) cultivars, planting date, fertility regime, pod sampling date, and pod location on Cercospora kikuchii incidence was studied in 1966 and 1967 at Southern Illinois University's Belleville Research Center. The results obtained indicate that the incidence of infected seed differs between the several indeterminate cultivars studied, but is similar to data reported for determinate cultivars. Planting date has a pronounced influence on seed infection, but is interrelated with cultivar and season. High relative humidity during floral stages apparently is a critical factor in predisposing soybean pods and seeds to C. kikuchii infection. Seed sampled from the upper half of soybean plants had a higher percentage of infected seed for several weeks than from the lower half of the plant.

PATHOLOGICAL ALTERATIONS OF TRANSMEMBRANE BIOELECTRICAL PROPERTIES, A. L. Karr and A. Novacky, University of Missouri, Columbia, MO 65201. The introduction of leaf-spot pathogens (or their toxins) into leaf tissue from a susceptible plant results in the rapid (10 min) loss of the plant cell's ability to recover transmembrane potential (PD) in the presence of 1 mM cyanide (CN). The recovery of PD in the presence of CN (CNR) has been shown to be a chlorophyll mediated process. A loss of normal oscillations resulting from a light/dark or dark/light signal accompanies the loss of CNR. These results suggest a rapid pathogen-caused effect at the level of either the chloroplast membrane or at the level of coupling of chloroplast derived energy with plasma membrane function.

GROWTH RESPONSES AND ULTRASTRUCTURAL CHANGES IN SOYBEAN INFECTED WITH GLOMUS MOSSEAE, T. S. Schubert and M. F. Brown, University of Missouri, Columbia, 65201. Experiments were conducted to examine the growth responses and ultrastructural interactions induced by the vesicular-arbuscular endomycorrhizal fungus Glomus mosseae in soybean, Glycine max var. Clark. In pot cultures, infected soybeans showed highly significant increases in both dry weight and total yield when compared to uninoculated control plants. Light microscopy accompanied by transmission and scanning electron microscopy revealed typical V-A mycorrhizae structures. Inter- and intracellular hyphae of the endophyte were present in the middle cell layers of the root cortex. Branches of these hypae terminated in finely bifurcate arbuscules within the innermost cells of the cortex. Vesicles were encountered infrequently.

FLORAL ABNORMALITIES IN VINCA ROSEA L. INDUCED BY THE SASSAFRAS BUNCH DISORDER, Chung-Jan Chang and D. F. Millikan, University of Missouri, Columbia, 65201. A bunch disorder was dodder transferred from sassafras to Vinca rosea L. Symptoms in Vinca are similar to those caused by the X-disease agent (XDA) but differs in causing a phyllody rather than the yellowing of the foliage. This disease resembles those caused by XDA and the aster yellows agent (AYA) by causing the floral parts to differentiate into leaf-like structures. Loss of floral characters includes four general stages; the first being a gradual transition of the petal color into green. During the second stage the entire flower assumes a green color yet retains petal integrity while the third features a reduction in size. Complete differentiation into sepal or leaf-like structures occur in the fourth stage. Histologically, the first stage reveals chlorophyll in the petals while the fourth stage shows the complete transition of floral to vegetative parts.

EFFECT OF VESICULAR-ARBUSCULAR (VA) MYCORRHIZAL FUNGI ON GROWTH OF YELLOW-POPLAR SEEDLINGS IN FOREST NURSERY SOIL, D. A. Starkey and M. F. Brown, University of Missouri, Columbia, 65201. Studies were conducted to determine the feasibility of inoculating nursery soil with VA mycorrhizal fungi to increase growth of yellow-poplar seedlings. Effects of three species of fungi were compared to define interspecific variations in

growth response. Nursery plots were inoculated with fungi and plant growth data was recorded throughout the season. Similar experiments were conducted with inoculated sterilized and non-sterile nursery soil under greenhouse conditions. Nursery seedlings outside the inoculated plots were sampled and examined for growth and percentage of the root system exhibiting mycorrhizal development. Seedling height, diameter and dry weight were found to be correlated with per cent mycorrhizal infection. Effectivity was established for the three species of fungi tested. Inoculation of nursery beds with VA fungi appears to be feasible and may improve seedling growth when soil sterilization is employed.

THE DISORDER STRAWBERRY STREAK OF FRAGARIA X ANANASSA DUCH, ANATOMICAL CHARACTERISTICS OF THE LEAVES, ENVIRONMENTAL INFLUENCE ON EXPRESSION AND A GENETIC HYPOTHESIS FOR CONTROL, G. R. Brown, State Fruit Experiment Station of SMSU, Mt. Grove 65711. Clonally propagated plants which had previously expressed strawberry streak symptoms were separated into two phenotypic classes. Class A, plants presently exhibiting streak symptoms and Class B those plants with symptom remission. The green portion of leaves from class B appear to contain more parenchyma cells than normal leaves. The chlorotic portion of leaves from class A appear to be thinner and the cells between the epidermal layers resembles parenchyma cells. Plants were placed in 4 environments for a period of 63 days. Additional symptom remission occured in the two environments that had lower light intensity (not measured) and cooler temperature 19 C and less than 19 C and normal day length (10.5-12.2 hr). No additional symptom expression or remission was observed in environments of 22 C, normal day length and 22 C 18 hr day length. A genetic hypothesis was proposed involving a nuclear inhancer gene and a plastid gene for a threshold type character.

EFFECT OF DEFOLIATION ON CARBOHYDRATE RESERVE IN THE RHIZOMES OF BIG BLUESTEM GRASS, John W. Reeves, Western Illinois University, Macomb, 61455. Three contact herbicides were compared with fire and no-treatment on a big bluestem prairie in southern Illinois. The selected herbicides were pentachlorophenol, paraquat, and endothall. Samples of the rhizomes were collected in the winter of 1975, following a no-treatment year and two consecutive treatment years and analyzed for total available carbohydrate (TAC). The TAC of the rhyzomes was reduced by all defoliating treatments. The reductions were 41 percent with pentachlorophenol, 40 percent with endothall, 37 percent with fire, and 29 percent with paraquat. Two consecutive years of defoliation in May, even when followed by a year of no-treatment, leaves carbohydrate levels below normal.

EFFECT OF MODIFYING STRIPS OF SOIL CONTAINING HIGH LEVELS OF CALCIUM ON VEGETATIVE GROWTH OF HIGHBUSH BLUEBERRIES (Vaccinium corymbosum L.), B. D. Fuqua and G. R. Brown, Agriculture Dept., Southwest Missouri State Univ., Springfield, and State Fruit Experiment Station of SMSU, Mt. Grove. Sulfur was applied in narrow strips to a Newtownia slit loam soil, initial pH 7.3 and calcium content of 4256 kg/ha, to lower the soil pH for production of highbush blueberries. Strips of soil 0.9m X 30.5m, amended with 293 g/m of sulfur, were alternated with untreated strips 2.1m in width. Ten blueberry cultivar-age combinations were transplanted into the treated area utilizing a randomized complete block design. Vegetative growth of plants has been satisfactory using this method for acidifying soils. Mean values of % plant survival, vigor, number of shoots per bush, and shoot growth in this planting are as high or higher than an identical planting on a low calcium soil where sulfur was broadcast applied. Neither planting exhibited noticeable nutrient deficiencies nor toxicities. The pH of the soils in treated strips is 4.8 while the untreated area remains pH 7.1.

AZALEA GROWTH AS AFFECTED BY N FORM, N CONCENTRATION AND LIGHT INTENSITY, Ray Maleike and Robert Holmes, Southern Illinois University, Carbondale, 62901. Four azalea cultivars were tested using 2 N sources, at 3 concentrations and 2 light intensities. All azaleas grew better under the higher light intensity. Azalea cvs. Hinodigiri and Sherwood Red had higher average shoot length under lower rates of N regardless of form. Higher rates of N decreased quality. The Poukhan azalea had the highest average shoot length at the higher rates of NO_3-N. High rates of NH_4-N resulted in diminished growth and quality of this cultivar. Azalea cv. Purple Splendor exhibited the best growth under the intermediate level of NO_3-N. High rates of NH_4-N caused diminished growth and quality.

CHEMICAL PINCH OF POINSETTIAS, R. L. Holmes, Southern Illinois University, Carbondale, 62901. UNI-P293(2,3-dihydro-5,6-diphenyl-1,4-oxathiin) and Tipnip(1-undecanol) were applied at three rates each to 'Dark Red Hegg', 'White Hegg', 'Diva Hegg', 'Mikkel Triumph', 'H-2', 'H-15', and 'Paul Mikkelsen' poinsettias. Applications were single treatments of foliar spray to runoff. Final height, date of anthesis, bract diameter, and number of bracts were recorded at anthesis. Initial foliar burn was evident with Tipnip. Leaf distortion resulted from UNI-P293. Anthesis was delayed with some treatments and both chemicals were effective in height reduction. Some treatment resulted in increased bract count.

FOAM AS A CARRIER FOR GROWTH RETARDANTS ON POINSETTIA, J. M. Cox and R. L. Holmes, Southern Illinois University, Carbondale, 62901. The growth regulators A-Rest (ancymidol) and B-Nine (SADH) were applied as a single application, in conventional foliar sprays and at three rates each with a foam carrier to 'Paul Mikkelsen', 'H-2', and 'H-15' poinsettias. Final height, date of anthesis, and bract diameter were recorded at anthesis. Foliar damage was exhibited at high levels of regulators in foam. Bract size was reduced and anthesis was delayed in some treatments. A-Rest resulted in greater height reduction than B-Nine. Highest levels of foam carried regulators resulted in lower quality plants.

A GENETIC STUDY OF FLOWER COLOR VARIATIONS OF IMPATIENS SULTANI, HOOK. F., James I. Gray and Oval Myers, Jr., Southern Illinois University, Carbondale, IL 62901. Crosses between two cultivars of Impatiens sultani, Hook. f. (2n=16), I. sultani 'Futura' burgandy and I. sultani 'Shade King' white, indicated the existence of at least seven independently segregating loci, I, C_1, C_2, D_1, D_2, O and P which are responsible for flower coloration. A dominant temperature sensitive color inhibitor gene, I, appears to be transmitted at temperatures below 20 C but is not transmitted at temperatures above 27 C. C_1 and C_2, two dominant color genes at independent loci are required for color in the absence of I. The gene, P, gives purple coloration when homozygous dominant and the gene, O, produces orange coloration in the absence of homozygous dominant P. Color variations between extremes which give such colors as red, pink, orange pink, pink and light pink are explained by two loci of additive dilution genes, D_1 and D_2.

PRODUCTION OF APPLE PLANTLETS BY TIP MERISTEM CULTURE, Shu-Ching Huang and D. F. Millikan, University of Missouri, Columbia 65201. Tip meristem culture is useful for obtaining pathogen-free cultivars of many economically important plants. We are using this technique to eliminate the stem grooving virus (SGV) from certain clones of apple, Malus sylvestris Mill. Routine methods for eliminating SGV infection have been unsuccessful. Meristems of 0.5 mm have been asceptically transferred to filter bridges inverted over a liquid media composed of the B-5 organic components of Gamborg et al (Exp. Cell Res. 50:151) and the inorganic components of Mirashige and Skoog (Physiol. Plant 15:473) plus 2% sucrose. This must be supplemented with benzyladenine and gibberellic acid (GA_3) at molar conc of 5×10^{-7} and 10^{-7}, respectively. Meristems must be transferred after one day due to the presence of inhibitory phenolic substances. After 3 additional transfers of 7 day intervals, plantlets of approximately 5 cm in length develop. Aside from the absence of roots, these plantlets are fully differentiated. Present efforts are being extended to initiate roots and complete plants.

MERISTEM CULTURE OF JUGLANS NIGRA L., Anna Lenartowicz and D. F. Millikan, University of Missouri, Columbia 65201. Black walnut, Juglans nigra L., is an important tree species in Missouri for the veneer industry. The kernels of its fruit are used in the dairy and confectionary industries while the shells make useful abrasives and a high grade charcoal. The bunch disease, presumably of mycoplasma-like etiology, and the ambers disorders interfere with profitable production of both wood and nuts. Consequently, we have initiated a tip meristem program for the propagation of pathogen-free clones of J. nigra. Meristems (0.8 to 1.0 mm) have been moved asceptically to filter paper bridges inverted over a liquid media composed of vitamins from the B-5 formula (Exp. Cell Res. 50:151), the mineral components of the MS media (Physiol. Plant. 15:473), 2% sucrose, coconut milk, hormones and amino acids. Meristems will increase 8 fold in size before a lethal browning action occurs. Presently we are developing a chemically defined media to eliminate this lethal browning and differentiate a complete plant.

RESOURCE PRODUCTIVITY ON SOYBEAN FARMS IN RIO GRANDE DO SUL, BRAZIL, Vincent Cusumano and Joseph Vercimak, Southern Illinois University, Carbondale, IL 62901. This paper describes a typical soybean farm in southern Brazil and attempts to estimate the relative economic efficiency of the factors of production in producing soybeans. The descriptive analysis indicated that the average soybean farm planted 74 percent or 204 hectares of its available land in soybeans. Wheat was raised on 151 hectares and 41 hectares were utilized for livestock. An analysis of resource use indicated an extremely land intensive production process. An argument for greater emphasis on educational programs is also made based on the results.

WORLD FOOD RESERVE: FARM TOOL OR WEAPON, Walter J. Wills and Donald W. Lybecker, Southern Illinois University, Carbondale, IL 62901. In the early 1960's there was a world food reserve of 90+ days. In the mid 70's this reserve was reduced to 21 days. This reduced food reserve contributed to farm price instability and a world wide food price inflation. Such reserves can contribute to farm income stability and consumer price stability but the politics of inventory management of such magnitude suggests food reserves may be a weapon that works against income stability, protection against hunger and may even further contribute to the conflict between the more developed and the less developed countries.

A METHOD FOR ESTIMATING THE SIZE OF A POPULATION OF LOCAL FISHERMEN, Kenneth Chilman and Marvin Brown, Southern Illinois University, Carbondale 62901. The objective of this research was to develop a method for estimating the size of a local fishermen population. "Local" was defined as fishermen residing in five counties adjacent to the Current River in Missouri. A method of measuring wildlife populations by capture-recapture ratios called the "Peterson Index Method" was adapted for use. The population estimate of 418 could be improved by stratifying fishermen by hours spent fishing.

BOTANY

THE NIDULARIACEAE (BIRD'S NEST FUNGI) IN ILLINOIS. Barbara J. Parady and Walter J. Sundberg. Dept. of Botany, Southern Illinois University, Carbondale, IL 62901. Five species of Nidulariaceae (Bird's Nest Fungi) occur in Illinois. Crucibulum laeve (Huds. ex Relh) Kambly, Cyathus stercoreus (Schw.) de Toni, and Cyathus striatus Huds. ex Pers. occur throughout the state while Cyathus olla Batch ex Pers. and Nidularia pulvinata (Schw.) Fries appear at present to be restricted to the northern and southern parts of the state respectively. Herbarium and field studies resulted in several new county distribution records for each species indicating the need for increased mycological exploration in Illinois.

FACTORS INFLUENCING WHITE OAK DECLINE, Dean M. Rockwell and Virgil K. Howe, Western Illinois University, Macomb, 61455. The rhizosphere soils and fine root development of eight white oaks (Quercus alba L.) were studied. Six trees were growing in lawn-like conditions but differed in that two exhibited decline symptoms; two healthy trees were growing in semi-open canopy conditions; and two healthy trees were solitary in location. The remaining two trees were healthy forest trees selected as controls. Comparisons of soil characteristics indicated little differences except for high phosphorus levels found in the soils under the solitary trees. The fine root development was comparable for all trees except for one solitary tree which had a high incidence of a smooth black corraloid type of ectomycorrhizae.

THE INFLUENCE OF DEER ON THE STRUCTURE AND COMPOSITION OF HEMLOCK FORESTS, Roger C. Anderson, Illinois State University, Normal, Illinois, 61761. To assess the impact of deer browsing on the composition, and structure of hemlock dominated forests, comparative studies were made of heavily browsed areas, that had been under protection for 4 or 12 years, with forests with low deer density. Our results suggest that in portions of northern Wisconsin, hemlock has not been successfully reproducing itself for, perhaps, as long as 40 years, resulting from the expansion of the deer herd that began in the 1930's. Because of the ability of sugar maple to withstand browsing pressure, hemlock dominated forests are rapidly being converted to sugar maple.

A 30-YEAR RECORD OF TREE GROWTH IN STRIP MINE PLANTINGS, W. Clark Ashby and Clay A. Kolar, Southern Illinois University at Carbondale, 62901. Plantations of black locust and of shortleaf pine were established in 1938-9 on an ungraded strip mine near DuQuoin, IL. In April 1947 these plantations were underplanted with 9 hardwood species. Tulip tree, silver maple, black walnut, and black locust made good growth in the black locust area. Shortleaf pine and underplanted black locust grew well in the pine area. Sweet gum and osage orange grew less well in either plantation, and ash and cottonwood died. Large numbers of elm and box elder volunteered in both plantations. Hackberry invaded vigorously under the black locust. Basal area (sq. ft./ acre) totalled 97 on the locust and 72 on the pine area

ALLELOPATHY IN THE FIRST STAGES OF SECONDARY SUCCESSION ON THE PIEDMONT OF NEW JERSEY. James R. Jackson and Roger W. Willemsen (Dept. of Biology Missouri Southern State College, Joplin, Mo.) Ambrosia artemisiifolia (ragweed) is a dominant species in the first year old field succession but rarely persists for more than two years. Ragweed and Raphanus raphanistrum (wild radish), also an early invader, failed to become re-established in plots cleared of second stage perennial vegetation (dominated by Aster pilosus), despite the large number of seeds of these primary invaders present in the soil. Edaphic experiments revealed that this pattern of succession was not due to mineral or physical properties of the soil. Field soil from the second stage of succession inhibited the growth and germination of ragweed and wild radish while soil from the first stage had no effect. Inhibitory volatile materials from ragweed were not detected. However, root exudate of ragweed, and shoot extracts of ragweed and aster inhibited the germination and growth of early invaders of abandoned fields. These results indicate that the vegetational change from the first to the second stage of succession may be mediated at least partially by an allelopathic response. Chromatography and bioassay techniques revealed the inhibitory compounds to be phenolic acids, including caffeic and chlorogenic acids.

RELATIONSHIPS BETWEEN NUCLEAR FEULGEN DNA AND NUCLEAR DRY MASS IN ONION, F. B. Kulfinski, Southern Illinois University, Edwardsville, 62025. Relative nuclear area increased from 1x at the base to 2.7x at the equator to 2.0x at the apex of onion bulb, nuclear dry mass per unit area increased from 1x to 1.5x to 1.4x, nuclear dry mass from 1x to 4.2x to 2.8x, and nuclear Fuelgen DNA from 1x to 3.6x to 1.8x. Constancy of DNA in plants is rejected and relation of nuclear parameters to cell size is hypothesized.

EFFECT OF FUSARIUM MONILIFORME ON NUCLEI AND NUCLEOLI OF ONION EPIDERMIS, F. B. Kulfinski and H. L. Monoson, Southern Illinois University, Edwardsville 62025, and Bradley University, Peoria 61625. Fusarium moniliforme was isolated from white onion, cultured, and inoculated into holes bored in onion bulbs. After 48 hours, nuclear dry mass of host nuclei 0-5mm ahead of mycelium decreased by 19% as determined by quantitative interference microscopy. Nucleolar dry mass declined by 34% under the same conditions. Degradation and/or exit of nuclear and nucleolar macromolecules is suggested.

PHYTOPLANKTON PERIODICITY IN WINTERS POND, UNION COUNTY, ILLINOIS, Marcia M. Grady, Southern Illinois University, Carbondale, 62901. Quantitative investigations of the phytoplankton of a swamp-fed pond were carried out for a one-year period. Various physical and chemical parameters were studied in relation to phytoplankton periodicity. Periodicity was observed to be closely related to seasonal light and temperature changes. Total phytoplankton density reached a maximum of 4498 pl/ml in July. The summer phytoplankton community was dominated by the Chlorophyta, fall phytoplankton dominated by the Pyrrhophyta, while the winter phytoplankton was dominated by the Chromophyta. A minimum total phytoplankton density of 419 pl/ml was observed in January. Continuous turnovers in phytoplankton dominance were observed in the spring.

THE ESTABLISHMENT AND DISTRIBUTION OF THE FRESHWATER RED ALGA, BANGIA ATROPURPUREA (ROTH) C. AG., IN ILLINOIS WATERS OF LAKE MICHIGAN, Kenneth L. Weik, Lake Forest College, Lake Forest, 60045. In recent years the freshwater red alga, Bangia atropurpurea has become widely established in supralittoral habitats along the Illinois shoreline of Lake Michigan. Preliminary investigations reveal its presence in an almost continuous band from the Illinois-Wisconsin state line to as far south as Chicago. Peak development typically is reached in mid-summer and the plants often form a coassociation with Cladophora. Reproduction and probable modes of entrance to Lake Michigan will be discussed.

SOME SCANNING ELECTRON MICROGRAPHS OF LUPINUS BILINEATUS AND L. CAMPESTRIS AND AN F_2 HYBRID, Leandra M. Schaller and David B. Dunn, (University of Missouri, Columbia) SEM was utilized to enhance the study of the morphology of L. bilineatus and L. campestris and an F_2 hybrid. Leaf, stem and petiole pubescence from these plants and pollen from the hybrid were studied. The pubescence of L. bilineatus is much longer than that of L. campestris. The hybrid possesses a pubescence which is intermediate between the two parents. The leaves exhibit structures which which are thought to be forerunners of trichomes. The hybrid pollen is tricolporate.

SOME ASPECTS OF THE LIFE HISTORY OF ISOTRIA MEDEOLOIDES, AN ENDANGERED ORCHID SPECIES, Mike Homoya, Southern Illinois University, Carbondale, 62901. Research during 1976 was conducted to determine environmental, phenological and developmental aspects of the life history of Isotria medeoloides in Illinois. Various instruments and sampling techniques were used to describe characteristics of the microclimate and vegetation at the site. Results of compiled data show seasonal patterns of atmospheric temperature, soil temperature, vapor pressure deficit, soil moisture and precipitation. Records over the past four growing seasons show early termination of capsule development and seed mortality due to late summer environmental stresses. This fact along with the natural phenomenon of extremely low frequency of seed germination characteristics of members of the Orchidaceae suggest reduced reproductive potential for this species at this site.

GEOGRAPHICAL DISTRIBUTION AND TAXONOMIC STATUS OF HEUCHERA MISSOURIENSIS ROSENDAHL. Robert H. Mohlenbrock and Paul W. Nelson, Southern Illinois University, Carbondale, 62901. Heuchera missouriensis is known only from Madison and Wayne counties, Missouri, where it was first discovered by Steyermark on bluffs along the St. Francis River. The original stations have been rediscovered. The taxonomic status of this taxon has been clarified by SEM studies of the seeds.

FLORA OF CEDAR LAKE RESERVOIR, JACKSON COUNTY, ILLINOIS, Thomas Heineke, Southern Illinois University, Carbondale, 62901. Cedar Lake Reservoir is located approximately five miles south of Carbondale in southern Illinois. The area investigated consists of about three thousand acres within the Shawnee Hills Physiographic Division. High habitat diversity results from the very rugged topography. Pennsylvanian-aged bedrock underlies most of the region. Over eight hundred and fifty species of vascular plants have been collected and identified from the Cedar Lake area. Among these, several unusual records were made for southern Illinois.

FLORISTIC STUDY OF THE OLIN NATURAL AREA, Deborah L. Thompson, Southern Illinois University, Edwardsville, 62026. A floristic study was conducted on the Olin Natural Area near Alton in Madison County, Illinois. This area is currently being considered for dedication under the Illinois Nature Preserve Act. The Olin tract contains Mississippi River bluff, a small hill prairie, deciduous forest, ravines and karst topography characteristic of the glaciated section of the Middle Mississippi Border Division. On the 297 acres 450 vascular species have been identified, of these two are listed Federally threatened.

A FLORISTIC MODEL OF THE ST. FRANCOIS MOUNTAINS IN THE MISSOURI OZARKS, Paul Nelson, Southern Illinois University, Carbondale, 62901. A floristic study was conducted during the growing seasons of 1975-77 to determine species composition using a model area which would display both diversity, past plant migrations, and a maximum of transition zones across physiographical features. Plant diversity is perhaps most revealed at Johnson's Shut-Ins State Park, Reynolds County, Missouri, in the St. Francois Mountains where Pre-Cambrian crystalline rock and Cambrian sandstone, limestone, and dolomite sediments were sampled for species composition. As a result, a great diversity of habitats has revealed a total of 890 taxa, including glacial relicts, endemics, unusual and endangered species, and two state records.

ALIEN FLORA CHANGES IN TWO WEST-CENTRAL ILLINOIS COUNTIES DURING THE PAST 140 YEARS. R.M. Myers and R.D. Henry, Western Illinois University, Macomb 61455. Collection records from 1833 to 1976 for 301 aliens in Hancock and McDonough counties indicate one-third (75% cultivated), including 5 sole Illinois records, should be excluded because of no collections for 24 to 130 years. Of the remaining 207:(a) over 27% have been reported since 1952, (b) 79% are naturalized and the rest casuals,(c) 83% are from the Old World, 11% from the U.S., and 5% from New World tropics,(d) 55% have been cultivated,(e) over 90% occur throughout Illinois, (f) 84% are weeds in the U.S.,(g) 91% grow in disturbed mesic habitats and only two species are aquatics. Of 1121 species recorded (820 natives and 301 aliens), 130 natives are extinct and 97 aliens excluded. Conclusion: aliens comprise 23% of the present flora compared to 6% in 1846 after settlement began.

RARE AND ENDANGERED VASCULAR PLANTS IN ILLINOIS. John E. Schwegman, Illinois Department of Conservation - Natural Areas Section, Springfield, 62706. This paper discusses the proposed and pending federal program for the protection of rare and endangered plant species. It will include a listing and brief statement of status of the species proposed for endangered status in Illinois, and a discussion of the regulations proposed for their protection. The need for a state program to protect endangered plants and the current status of state efforts will also be discussed.

UPDATE ON THE VASCULAR FLORA OF ILLINOIS. Douglas M. Ladd and Robert H. Mohlenbrock, Southern Illinois University, Carbondale, 62901. During the last several years, a substantial number of vascular plants have been discovered for the first time in Illinois. Several of the records have extended the ranges of the species significantly.

NEW DATA RELATED TO SPECIATION IN NOTHOLAENA STANDLEYI MAXON. David S. Seigler, Department of Botany, The University of Illinois, Urbana, Illinois. Notholaena standleyi Maxon was first described by Hooker in 1864. Since that time it has been considered by most workers to be a single species. It is a wide ranging xeric fern occuring from central Texas to Southeastern Colorado to Arizona and thence south into central Mexico. Correll in the "Ferns of Texas" indicated the presence of two "color forms" but did not see a clear delineation between them. Our recent studies have found a third form. Each of the three forms occupy a distinct range, have specific edaphic requirements and a characteristic chemical composition of the ceraceous exudate. Studies of speciation in this group are complicated by problems of apomixis. It appears that what has been described as one species is a complex of three closely related, but distinct taxa.

CHEMICAL STIMULI FOR OVIPOSITION IN MANDUCA SEXTA PRODUCED BY AQUEOUS FRACTIONS OF TOBACCO, Lee Tichenor and David Seigler, Department of Botany, University of Illinois, Urbana, 61801. Water extracts from dried tobacco have been shown to induce oviposition by Manduca sexta on leaf surrogates. Fractions of water extracts from silica gel, polyamide, and sephadex columns have given positive responses in electroantennagram analysis. Gas chromatography of active fractions on XE-60 show several similarities in peak patterns. These are presently being collected and bioassayed with the antennagram assay. The positive chemicals are to be characterized and presented to intact insects for behavior studies.

CYANOGENESIS IN MARASMIUS OREADES, Stephen G. Saupe and David S. Seigler, University of Illinois, Dept. of Botany, Urbana, 61801. The mycelial stage of the fairy ring fungus, Marasmius oreades (Bolt. ex Fr.) Fr., produces hydrogen cyanide when grown in malt-yeast-glucose shake cultures. Cyanide was detected in both the culture medium and the head space gases. Cyanide produced by the fungus was trapped in sodium carbonate and then colorimetrically quantitated. Non-volatile cyanide, in an unknown bound form, appears to be excreted into the culture medium during exponential growth. Concomitantly, the culture medium pH rapidly declines. Free hydrogen cyanide is apparently liberated from the culture medium by a pH-mediated hydrolysis of the unknown cyanogen that accumulates during active mycelial growth. Although an apparent secondary metabolite, cyanide is a constant product of metabolism of M. oreades.

NUCLEAR AND NUCLEOLAR CHANGES IN ONION EPIDERMAL CELLS MEASURED CYTOCHEMICALLY AND INTERFEROMETRICALLY FOLLOWING EXPOSURE TO AMBIENT ATMOSPHERE, W. S. Courtis and A. J. Pappelis, Southern Illinois University - Carbondale, 62901. Exposure of onion leaf base outer epidermis to the ambient atmosphere resulted in an increase in nucleolar size, nuclear dry weight, nucleolar area, nuclear RNA, and nuclear protein content while nuclear DNA content and an average number of nucleoli per nucleus remained unchanged. Wounding exposured tissue resulted in similar measurements except that the increase in nuclear area was not as great.

QUANTITATIVE INTERFERENCE MICROSCOPY USING PHOTO-MICRODENSITOMETRY, W. S. Courtis and A. J. Pappelis, Southern Illinois University - Carbondale, 62901. A Leitz interference microscope equiped with an Orthomat camera was used to photograph cells with interference fringes (546 nm light) in view (calibration frame) and with fringes spread to yield even-field backgrounds (measuring frames) with retardations of 10, 20, 30, 40, and 50% of a wavelength advanced beyond that observed in the calibration frame. Photomicrodensitometry scanning and recording equipment yielded photometry values for the nucleus that were converted to optical path difference values (OPD). Nuclear dry mass determined by this method was within 10% of that determined visually.

NUCLEAR DRY MASS VARIATIONS OF COTYLEDON EPIDERMIS IN GLYCINE MAX, Song-chiau Lee, P. Mumford, A. J. Pappelis, and J. N. BeMiller, Southern Illinois University, Carbondale, 62901. Glycine max was studied using quantitative interference microscopy. Using monochromatic light, the nuclear dry mass (NDM) was determined in three varities. The increase in NDM in Wayne, had reached maximum values by 5-8 days after planting and senesced during 8-18 days. Essex reached maximum values 6-10 days after planting and senesced during 14-26 days. William reached maximum values 10-14 days after planting and senesced during 18-24 days. These provide new models for study of variation in development and senescence within the same species. Senescence phase is defined as NDM decline.

NUCLEAR DRY MASS, NUCLEAR AREA, NUCLEOLAR DRY MASS, AND NUCLEOLAR AREA IN LEAF HAIR CELLS OF MAYAPPLE DURING NORMAL AGING, Song-chiau Lee, A.J. Pappelis, and J.N. BeMiller, Southern Illinois University - Carbondale, 62901. The nuclear dry mass (NDM), nuclear area (NA), nucleolar dry mass(NoDM), and nucleolar area (NoA) of leaf hair cells in Podophylum peltatum were measured with an interference microscope during normal aging. For the first and last sample NDM was 34.8 and 7.3 x 10^{-11}g; NA, 25.3 and 11.4 x 10^{-7}cm^2; NoDM, 2.2 and 0.28 x 10^{-11}g; and NoA, 3.5 and 0.35 x 10^{-7}cm^2. The four parameters showed these decreases from the time leaves enlarged until the time they became yellow.

INFLUENCE OF 2,4-DICHLOROPHENOXYACETIC ACID ON THE MORPHOLOGY, CYTOLOGY AND CHLOROPLAST STRUCTURE OF GREENING RADISH COTYLEDONS. M.J. Nadakavukaren and D.A. McCracken, Illinois State University, Normal 61761. Dark-grown radish seedlings were sprayed with 1 x 10^{-3} M sodium salt of 2,4-D and were exposed up to 48 hr of light. The 2,4-D-treated cotyledons remained unexpanded and closed while the untreated cotyledons expanded and opened within 48 hr. Differences in cell size, wall thickness, and intercellular space were observed between the treated and untreated cotyledons. A normal development of etioplast to chloroplast with the formation of a typical grana-fret work system was observed in the untreated cotyledons while the development of etioplasts to chloroplasts was altered in the 2,4-D-treated cotyledons.

INFLUENCE OF 2,4-DICHLOROPHENOXYACETIC ACID ON CHLOROPHYLL CONTENT AND PHOTOSYNTHETIC RATE IN GREENING RADISH COTYLEDONS, Derek A. McCracken and Mathew J. Nadakavukaren, Illinois State University, Normal, 61761. Etiolated radish cotyledons were sprayed with 2,4-D, placed in light, and then sampled over a 72 hr period. The chlorophyll content of treated plants was less than that of controls but the rate of chlorophyll biosynthesis was unaffected. The photosynthetic rate/mg chlorophyll was considerably higher for 2,4-D treated plants indicating that 2,4-D treatment resulted in a decrease in the size of the photosynthetic unit.

REPORT OF ANOMALOUS SECONDARY GROWTH IN PENSTEMON BRIDGESII (SCROPHULARIACEAE) AND STANLEYA PINNATA SSP PINNATA. Donald Bissing, Dept. of Botany, Southern Illinois University, Carbondale, 62901. P. bridgesii and S. pinnata are secondarily woody plants sharing a common montane habitat and mediterranean climate. These species also share an unusual pattern of secondary xylem deposition consisting of concentric rings of normal xylem alternating with rings of juvenile xylem in which vessel elements mimic the lateral wall thickenings of primary xylem. That this pattern occurs in two unrelated species suggests the operation of an adaptive strategy of a general nature designed to cope with a specific set of ecological demands. Further study is planned concerning the episodic nature of xylem deposition and its relationship to the phenology of the species.

CHEMISTRY

BIOCHEMISTRY OF AGING, Daniel Kamper and Jacklyn Melchior, Chicago College of Osteopathic Medicine, Chicago, 60615. We have been investigating the use of certain biochemical parameters such as collagen cross linking, thermal denaturation of DNA and hepatic enzyme changes to measure the biochemical age of an organism, as compared to its chronological age. The use of such "clocks" in aging research would negate the necessity of long term experiments. It has been reported that the life span of the rat can be increased by periodic fasting during the first year of life. We have taken advantage of this observation to develop two groups of rats (FISCHER 344) that are genetically identical but have different life spans. The degree of collagen cross linking was among the biochemical parameters determined. A significant decrease in the amount of collagen cross linking in the fasted group was observed as compared to their littermate controls.

EFFECT OF AGE ON THE RESPIRATION OF BRAIN AND HEART MITOCHONDRIA, Danny Yih-Joung Chiu and Arlan Richardson, Illinois State University, Normal, 61761. Mitochondria were isolated from the brain and heart of 3 to 38 month old rats obtained from the NIH animal colony. Respiration by the mitochondrial preparations was followed by measuring the oxygen consumption in a Gilson Respirometer. The

respiratory control ratio (the ratio of oxygen consumption during active ADP stimulated respiration and after ADP phosphorylation) also was determined. Respiration was determined using either succinate, pyruvate, palmityl-carnitine, or glutamate as substrate. There appears to be no over all change in respiration with age in either heart or brain mitochondria.

A CHEMICAL MODEL FOR THE MONOOXYGENASE ENZYMES. Shailendra K. Chaudhary, Robert W. Murray, Department of Chemistry, University of Missouri-St. Louis, Missouri 63121. A carbonyl oxide is being studied as a possible chemical model for the monooxygenase enzymes. This carbonyl oxide can be produced by the reaction of singlet oxygen with diphenyldiazomethane by 1) photosensitization method and 2) decomposition of triphenylphosphite ozonide. The carbonyl oxide oxidizes naphthalene to α and β naphthols probably via an arene oxide i.e. via National Institute of Health (NIH) shift. The support of the mechanism comes from the observed ratio of α to β naphthols (85/15) and from oxidation of 1-chloronaphthalene to yield 2-chloro-1-naphthol. Studies of arene oxides which have been postulated to be the metabolites in polycyclic aromatic hydrocarbon (PAH) carcinogenesis are intended.

BRAIN METABOLISM OF A CENTRAL BIOGENIC AMINE, R. Borison, P. Maple, M. Levin, R. Olsauskas, H. Havdala and B. Diamond, Mt. Sinai Hosp. & The Chicago Medical School, Chicago, 60608 & 60612. 2-Phenylethylamine (PEA) is an endogenous amphetamine-like central stimulant concentrated in the limbic system of human brain. Clinical studies show abnormalities in the urinary excretion of PEA among patients with depression, mania, schizophrenia or alcoholism. To study the brain metabolism of PEA we administered intraperitoneal injections of its radiolabeled amino acid precursor, L-phenylalanine to mice, and after ten minutes sacrificed the animals. Biosynthesis of PEA was measured by quantitating the radiolabeled PEA in brain. In animals made tolerant to ethanol in their drinking water we found an increase in PEA biosynthesis to 167 ± 5% of control, this increase indicates that ethanol has very marked effects upon PEA brain metabolism and that PEA may possibly be involved in the alcoholic state. (Support by GR2-529-712)

CHARACTERIZATION OF OPTIMUM CONDITIONS FOR RNA SYNTHESIS IN ISOLATED LIVER PARENCHYMAN CELLS, Bill Kreamer, Daniel S.H. Liu, and Arlan Richardson, Illinois State University, Normal, 61761. Although isolated liver parenchymal cells (ILPC) from rats have been widely used to study metabolic process, their use in the study of RNA synthesis has been limited. ILPC incorporate orotic acid into RNA at a greater rate than either uracil or uridine. Therefore, the incorporation of radioactive orotic acid into acid precipitable material was used as a measure of RNA synthesis. The conditions required for optimum RNA synthesis were found to be similar to conditions required for optimum protein synthesis. RNA synthesis was also found to be a function of cell concentration.

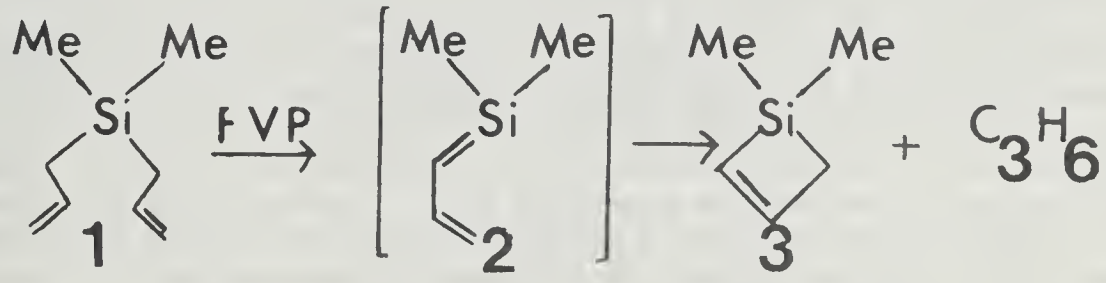
DNA Synthesis in Isolated Hepatocytes:-Morley, C.G.D.Dept. Biochem.,Rush-Pres.St. Luke's Medical Center, Chicago, Illinois, 60612

Hepatocytes isolated between 12 and 16 hr. after partial hepatectomy are unable to enter S Phase in culture. However cells isolated between 18 and 24 hr. are able to complete the round of DNA Synthesis initiated *in vivo*.Cells uncommited to DNA Synthesis *in vivo* are not stimulated to enter S Phase by media enrichment with metabolites or supplementation with serum, insulin or glucagon. Factors necessary to commit hepatocytes to the S Phase seem to be lacking in the culture environment. Normal hepatocytes, however, show significant increases in DNA Synthesis when stimulated with hydrocortisone. Whether this hormone is the 'commitment to S Phase' factor is at present under investigation.

IRON INCORPORATION INTO RAT HEPATOCYTES. D. Grohlich, C. Morley, R. Miller and A. Bezkorovainy. Biochemistry Dept., Rush-Presbyt.-St.Luke's Medical Center, Chicago IL 60612.

Hepatocytes were isolated following *in situ* perfusion of rat liver with collagenase. Iron-59 was added at zero time to suspension-aliquots containing $2x10^6$ cells (70-80% viable by dye-exclusion) agitated at 37°C in culture medium at pH 7.4. Rapid cooling on ice stopped the reaction. Iron at normal rat plasma levels and when complexed with citrate was incorporated *via* Michaelis-Menten kinetics. No incorporation of Fe was observed from Fe-human transferrin complex or from ^{59}Fe-labeled rat serum. Ascorbate and ATP had no effect, but EDTA inhibited Fe incorporation. At much lower than physiological Fe-levels incorporation appeared to be simple diffusion. Isolated rat hepatocytes may absorb Fe chiefly as a small organic complex, and at normal plasma Fe levels *via* an enzymatic process.

1,1-DIMETHYLSILACYCLOBUT-2-ENE, Eric Block, Larry Revelle, University of Missouri-St. Louis, St. Louis, Mo. 63121. Flash vacuum pyrolysis of diallyldimethylsilane (1) at 700°C affords the previously unknown subject molecule (3). The molecule has been characterized by H^1 NMR, mass spectrometry, and IR. It is postulated that an intramolecular retro ene mechanism operates to generate a silabutadiene intermediate (2) which ring closes to the product. Experiments are in progress to trap the intermediate and explore the generality of the reaction in synthesizing related molecules.



COMPUTERIZED CONTROL AND DATA ACQUISITION IN GAS CHROMATOGRAPHY/MASS SPECTROMETRY, Philip J. Berger, Teknivent Corp., St. Louis, 63132. Technological advances in the last ten years have brought a rather expensive analytical tool into the price range affordable by most forensic chemistry labs. The use of minicomputers has further enhanced the utility of GC/MS by providing better instrument control and more effective data reduction methods. A turnkey computer system is described which allows the user to define and store instrument calibration and control parameters in a permanent file, obtain mass spectral plots and mass chromatograms, and produce printed reports on selected data from any GC run. The system described incorporates a novel interactive display monitor which permits the user to view the acquisition of spectra or chromatograms while they are being acquired.

ELECTROPHORETIC CHARACTERIZATION OF ISOLATED OUTER MEMBRANE COMPONENTS FROM SERRATIA MARCESCENS, David Brown and Joseph Tsang, Illinois State University, Normal, 61761. Previous studies on outer membrane (OM) of gram (-) bacteria have shown to contain various complexed components, anyone of which may mask or alter the characteristics of others. This study is to isolate individual OM components and determine their true characteristics. OM was isolated by the Osborn method. The aqueous/phenol method was used to separate the lipopolysaccharides (LPS) from the proteins and conjugated proteins. Polyacrylamide gel electrophoresis followed by differential staining showed that original OM has 1 major LPS component of 12,000 daltons and 3 major protein components of 12,000, 27,000 and 39,000 daltons. After separation of OM components by aqueous/phenol extraction, there was found a water-

soluble LPS of 16,000 daltons and a phenol-soluble LPS of 15,500 daltons which was in association with a protein. The amount of glycoproteins detected was negligible.

ALKALINE PHOSPHATASE ACTIVITY ASSOCIATED WITH VARIOUS ENDOTOXIN PREPARATIONS FROM SERRATIA MARCESCENS, Joseph Tsang, Jeffrey Landes, Warren Nehmer, and David Brown, Illinois State University, Normal, 61761. Although it has been suggested that alkaline phosphatase (EC 3.1.3.1) of gram(-) bacteria forms complexes with lipopolysaccharides (LPS), direct demonstration of its activity associated with LPS has not been reported. Since endotoxins are complexes of LPS and cell envelope proteins, we assayed in this study endotoxin preparations extracted by trichloroacetic acid, aqueous-phenol, and aqueous-ether methods. Active preparations were further separated by polyacrylamide gel electrophoresis(PGE) and stained for protein and LPS components as well as for enzyme activity. Our results show that aqueous-ether extracted endotoxin was the only preparation associated with significant activity. After PGE, three enzyme components with molecular weights of 110,000, 140,000 and 190,000 daltons were detected. In addition, the 110,000 component was found to exist as a complex with a LPS component.

IMMUNOELECTROPHORETIC CHARACTERIZATION OF LIPOPOLYSACCHARIDES PREPARED BY AQUEOUS ETHER EXTRACTION OF CELLS OF SERRATIA MARCESCENS, Warren Nehmer and Joseph Tsang, Illinois State University, Normal, 61761. The method of aqueous ether extraction of lipopolysaccharide (LPS) from gram-negative bacteria involves 0.9% saline in the extraction medium. However the effect of saline on the extraction process and the antigenicity of components in comparison with those isolated by aqueous ether has not been studied. Preliminary data show that there is no significant difference in the antigenicity between the LPS extracted with aqueous ether and those extracted solely by saline. These findings raise serious questions as to the mechanism of extraction by aqueous ether and as to whether the saline used in this method has more effect on the release of LPS than the aqueous ether mixture.

SUGAR COMPOSITIONS OF LIPOPOLYSACCHARIDES PREPARED BY AQUEOUS ETHER EXTRACTION OF CELLS OF SERRATIA MARCESCENS, Jeffrey Landes, Warren Nehmer, and Joseph Tsang, Illinois State University, Normal, 61761. Although immunoelectrophoresis and staining techniques indicate that various fractions isolated by aqueous ether extraction of whole cells of S. marcescens contain lipopolysaccharides (LPS), their sugar compositions have not been determined. In this study we analyzed the alditol acetate derivatives of various hydrolyzed fractions by gas chromatography. Our results show most of the fractions contain L-rhamnose (30-40%), D-mannose (6-11%), D-galactose (trace), D-glucose (30-48%), D- and L-glycero-D-mannoheptulose (6-7%), D-glucosamine (2-7%), and D-galactosamine (trace). These sugar compositions indicate that these fractions contain LPS, as well as other extracellular polysaccharides. Sugar analysis of homogeneous LPS fractions isolated by phenol extraction supports this suggestion.

AN ELECTRON SPIN RESONANCE STUDY OF THE MONONEGATIVE ION OF TRIPHENYLENE IN SOLUTION. R.H. Ahmed and M.T. Jones, University of Missouri-St. Louis, St. Louis, Mo. 63121. The g-values for alkali metal cation-triphenylene radical anion pairs have been determined from electron spin resonance spectral lines. Sodium and potassium show a small steady increase in the g-value as the sample is cooled from room temperature to the freezing point of the solvent (THF, MTHF, DME, etc). A large increase in the g-value for rubidium and cesium has also been observed but only after the temperature of -60°C is reached. From the g-value observations it can be concluded that triphenylene is ion paired with alkali metals and that the extent of ion pairing is a function of solvent, temperature and alkali metal. Structural aspects of ion pairing will also be discussed.

SOME COPPER (II) COMPLEXES OF 2-(*N*-MORPHOLINYLMETHYL) -3-QUINUCLIDINONE, *trans*-2-(2'-QUINOLYL) METHYLENE-3-QUINUCLIDINONE, AND RELATED LIGANDS. V.T. Wilcox, R.C. Dickinson, and G.J. Long (Dept. of Chem., Univ. of MO-Rolla, Rolla, MO 65401) and J.R. Wasson (Dept. of Chem., Univ. of NC, Chapel Hill NC 27514). Complexes of copper (II) salts with the title compounds have been prepared and characterized. These complexes are intended as a possible model for the copper (II) coordination site in the"blue" copper proteins. The spectral and magnetic properties indicate that the complexes have pseudotetrahedral microsymmetry around the central metal ion. These complexes exhibit a single line ESR spectrum with a large A tensor anisotropy similar to that obtained for the "blue" copper proteins. The bulk magnetic susceptibility values for each of the compounds are normal and indicate no intermolecular interactions. Although the ESR properties of these complexes are similar to those of the copper proteins, their optical properties are distinctly different.

AN E.S.R. STUDY OF SILVER ELECTRON CAPTURE AND ELECTRON LOSS CENTRES, D.R. Brown and M.C.R. Symons, Illinois State University, Normal, 61761 and University of Leicester, Leicester, England.

Following low temperature irradiation of frozen solutions of the Ag^+ ion, E.S.R. evidence has been obtained of electron capture by Ag, Ag_2, Ag_3, and Ag_4 units. Additionally superhyperfine structure on the spectra of these has enabled the mode of solvation of the parent ion to be studied and solvation numbers for Ag^+ in water and methyl cyanide are proposed. Similar studies of irradiated silver halide/ alkali halide mixtures have revealed a previously undetected silver electron excess centre, composed of a large number of silver nuclei, and possibly related to the primary excess centre formed in the photographic process.

A STUDY OF THE REACTIONS OF DIETHYLALUMINUM HALIDES WITH NITROGEN BASES IN ACETONITRILE, Pauline Bellavance and Joyce Corey, University of Missouri-St. Louis,St.Louis,63121. The reactions of diethylaluminum halides with 2,2'-bipyridine,1,10-phenanthroline, and 2,2',2"-terpyridine have been studied in acetonitrile. Adducts of general formulas $(Et_2AlCl)_2 \cdot bipy$, $Et_2AlX \cdot BB$(X=Cl ,BB=phen;X=Br,BB=bipy) $Et_2AlX \cdot 2BB$(X=Br,I,BB=phen; X=I,BB=bipy), and $Et_2AlX \cdot terpy$(X=Cl,Br,I) have been obtained. Formulations for these adducts are proposed on the basis of spectroscopic and conductivity measurements and are compared to the formulations observed for the adducts isolated from the reactions of AlX_3 with these nitrogen bases in acetonitrile.

SECOND-ORDER PERTURBATION EFFECTS IN BIMOLECULAR SOLUTION KINETICS, Kenneth S. Schmitz, University of Missouri-Kansas City, Kansas City, Missouri 64110. The general approach to perturbation kinetics is to assume linearization of the concentration in the rate expression. A theory is presented in which the second-order perturbation term for the reaction $A + B \rightleftarrows C$ is retained. It is shown that the initial rate constant of decay (k_{eff}) is of the form, $k_{eff} = k_f C_A(o) + (1 + \theta)k_r/(1 - \theta)$ where $C_A(o)$ is the total concentration of A and θ is the fraction of sites reacted at the final equilibrium. This result does not require exact knowledge of the equilibrium concentrations $\bar{C}_A + \bar{C}_B$ as in conventional expressions. Limitations on the size of concentration jumps is discussed (second-order effects are not negligible if the perturbation jump in B is in excess of 11% total B).

ELECTRON DONOR-ACCEPTOR COMPLEXES AS MODEL SYSTEMS FOR ANTIMALARIAL DRUG INTERACTIONS, C. C. Thompson, Southwest Missouri State University, Springfield, 65802, and N. E. Webb, Christian Brothers College, Memphis, TN, 38104. Quinoline-based antimalarial drugs such as pamaquine and chloroquine are thought to interact with DNA molecules by intercalation between adjacent DNA base pairs. In this work the mode of binding of electron donor-acceptor complexes for a group of substituted quinolines and naphthalenes with 9-dicyanomethylene-2,4,7-trinitrofluorene has been investigated by optical absorption and molecular orbital techniques. Trends in spectral and thermodynamic properties as well as theoretical calculations of orbital energies and complex geometries indicate that with a relatively large conjugated acceptor quinolines act as pi-electron rather than lone pair donors. These results support the intercalation model for antimalarial drug interactions involving the quinoline moiety.

AN EMPIRICAL METHOD FOR ESTIMATING CONFIGURATIONAL DEGENERACY FROM MAXIMA IN SCATCHARD PLOTS, Brinda Ramanathan and Kenneth S. Schmitz, University of Missouri-Kansas City, Kansas City, Missouri 64110. Curvature in Scatchard plots is indicative of either cooperative (positive) or excluded site (negative) phenomena in binding small ligands to a multi-site polymer. We present an empirical method for estimating configurational entropy in which n-1 sites adjacent to a bound site are excluded from additional binding of ligands. Simulated binding curves are used to calculate the configurational entropy ΔS_{config} as a function of n. A procedure is proposed to obtain the "remote" nearest-neighbor interaction energy from the Scatchard maxima.

A SYSTEMATIC ANALYSIS OF THE HELICAL PARAMETERS FOR CHROMATIN IN SOLUTION BASED ON HYDRODYNAMIC DATA, Kenneth S. Schmitz, University of Missouri-Kansas City, Kansas City, Missouri 64110 and Barbara Ramsay-Shaw, Duke University, Durham, North Carolina 22007. Chromatin appears to have a "repeat unit" substructure, composed of nuclease resistant "beads" separated by nuclease accessable "bridges". Quasi-elastic light scattering and sedimentation velocity methods were employed in a study of the hydrodynamic properties of chicken erythrocyte chromatin multimers, obtained by partial microccocal nuclease digestion. The monomer and dimer particles provided bead diameter (D) and bead separation (B) parameters, which were then employed in the Garcia de la Torre-Bloomfield model for a helix conformation to obtain the pitch (P) and number of repeat units per turn (m). The latter two parameters affect, respectively, the slope and translation of f vs n, where f is the friction factor and n is the number of beads. (Systematic set: D = 110Å; B = 235Å; P = 110Å; m = 5.3.)

ALKANE CHEMOTAXONOMY OF *ARBUTUS*, P. D. Sorensen, C. E. Totten, and D. M. Piatak, Departments of Biological Sciences and Chemistry, Northern Illinois University, DeKalb, Il. 60115. The relationship of the three species of *Arbutus* (Ericaceae) north of Mexico has aroused debate among American plant taxonomists over the years. In the herbarium one cannot readily discriminate specimens of *A. menziesii* and *A. texana* because of overlapping leaf morphology; however, in the field the two remain easily discernible on the basis of habit and habitat. To provide a chemical means of distinguishing these two species we investigated the n-alkane profiles in leaf waxes of the three U.S. species. The alkane analyses indicated the two morphologically overlapping but allopatric taxa have substantially different amounts at the C-17 level, thus reinforcing continued recognition of them as separate species.

A MICROMETHOD FOR THE DETERMINATION OF SERUM THEOPHYLLINE, Jacklyn Melchior and Howard Wasserlauf, Chicago College of Osteopathic Medicine, Chicago, 60615. Theophylline is useful in those cases of reversible airway obstruction which result from constriction of smooth muscle. Recently it has received attention in the prevention of respiratory distress in the neonate. However, there is evidence that the dosage regime to obtain specific serum concen-

tration in premature neonates will prove to be highly variable. Since the therapeutic range of theophylline is quite narrow, it appears that effective therapy must involve monitoring blood levels. We have modified the standard colorimetric method for theophylline so that determinations can be done on 0.1 ml of serum. Using this procedure in the pediatric population of our hospital has verified the great variability of dosage required to obtain suitable blood levels of the drug.

SEPARATION OF THORIUM FROM THE RARE EARTHS, F. H. Firsching and Michael D. Allen, Southern Illinois University, Edwardsville, IL 62026

A new method is being developed for the homogeneous release of the rare earths from chelates, followed by precipitation, while thorium is kept in solution. Two chelating agents are used; one relatively strong; diethylenetriaminepentaacetic acid, which complexes with thorium; and the other relatively weak, nitrilotriacetic acid, which complexes with the rare earths. Then solution conditions are adjusted to cause the slow and selective release of the rare earth from its weaker chelate. This procedure depends on the ratio of formation constants between two dissimilar chelates, rather than the usual solubility differences. Preliminary findins indicate that this approach has lead to a very efficient rare earth-thorium separation and should have application to other separation problems.

A ^{13}C NMR STUDY OF THE σ-DONOR/π-ACCEPTOR CHARACTER OF PHOSPHORUS, ARSENIC AND ANTIMONY LIGANDS IN $LNi(CO)_3$ DERIVATIVES, George M. Bodner, Stephens College, Columbia, 65201.

Previous work in our laboratories has suggested that variations in the ^{13}C NMR carbonyl chemical shift in $LNi(CO)_3$ complexes is dominated by variations in the extent of transition metal→carbonyl π back-donation, which is in turn a reflection of the net transfer of electron density from the ligand (L) to the metal carbonyl fragment. We have successfully used the carbonyl chemical shift in these derivatives to obtain a quantitative measure of the σ-donor/π-acceptor character of a number of phosphorus ligands. We wish to report herein an analysis of $R_3ENi(CO)_3$ derivatives {E = P, As, Sb; R = Me, Et, Bu, Ph} which suggests that the σ-basicity/π-acidity ratio for ER_3 ligands decreases in the order Sb > P > As.

PHOTOCHEMISTRY OF CYCLOPENTADIENYLIRON CARBONYL COMPLEXES, D. G. Alway and K. W. Barnett, University of Missouri-St. Louis, 63121. Photolysis of η^5-$C_5H_5Fe(CO)_2X$ (X=Cl,Br,I,NCS,SCN,SeCN) with monochromatic (366 or 436 nm) light results in efficient loss of CO as the dominant photoprocess:

$$\eta^5\text{-}C_5H_5Fe(CO)_2X \xrightleftharpoons{h\nu} \eta^5\text{-}C_5H_5Fe(CO)X + CO$$

This conclusion is based upon photoreactions with ^{13}CO and EPh_3 (E=P,As,Sb) in which the products are η^5-$C_5H_5Fe(CO)(^{13}CO)X$ and η^5-$C_5H_5Fe(CO)(EPh_3)X$ respectively. The thiocyanato complexes (X=SCN,NCS) undergo linkage isomerization, presumably through 16e$^-$ coordinatively unsaturated intermediates. Experiments designed to identify cleavage of the Fe-X bond suggest that photohomolysis or -heterolysis of this bond is not an important process for the subject complexes. Infrared, ^1H NMR, and mass spectral data supporting these contentions will be presented.

ENGINEERING & TECHNOLOGY

POTENTIAL AIR-CONDITIONING ENERGY SAVINGS WITH AN ECONOMIZER, H.J. Sauer, Jr. and R.H. Howell, University of MO - Rolla, 65401. Air economizer operation is based on using outdoor air for "free" cooling whenever its temperature and humidity permit, thereby reducing operating time of the air-conditioning compressor. In this study, both commercial and residential buildings were analyzed from actual hour by hour weather data using the AXCESS-UMR computer program. Several control modes for the economizer were simulated. Results indicate that the potential savings are very dependent on the type of control used as well as the type of HVAC system. Significant savings in air-conditioning energy requirements are shown to be possible.

RAIL JOINT FAULT DETECTION SYSTEM - M.E. Cerulo, T.D. Pickett, C.A. Goben, T.P. Van Doren, University of MO - Rolla, 65401. A rail joint fault detection system has been designed encompassing several data acquisition techniques. An optical scanning sub-system detects the presence of gaps between rails at joints and, upon detection, measures the gap distance. This information provides key signals to a microwave sub-system which measures vertical and horizontal displacements between the rails at the joint. Initial decisions are made by the system as to the severity of the fault and actual measurements are provided to an operator in cases of unacceptable fault parameters.

AN OPTIMIZATION OF A HIGH PERFORMANCE 800MHZ LAND MOBILE RECEIVER, Charles F. Clark, Northern Illinois University, DeKalb, 60115. The Federal Communication Commission has recently made the 806-866MHz band available for land mobile use. It is the purpose of this paper to discuss an economical utilization of this spectrum space. Use of new technology will be developed where cost effective. Special attention will be paid to the development of the front end filter. A comparison of surface acoustic wave and conventional filter will be made. Final evaluation will be based on noise figure, intermodulation distortion and economic considerations. A cost effective design will be presented.

FOLDED DIPOLES INPUT IMPEDANCE - G.C. Clerici, University of MO - Rolla, 65401. A general expression, in matrix form, is developed for the input impedance of Folded Dipoles to allow the synthesis of new broadband antennas in the frequency range 3 MHz - 3 GHz.

CHARACTERIZATION OF CONSUMER MICROWAVE RECEIVERS IN THE X BAND AND K BAND REGIONS, Kenneth D. Hartman, Northern Illinois University, DeKalb, 60115. The paper discusses design considerations for a low cost microwave receiver with regards to sensitivity, directivity, frequency response and fabrication costs. Existing receivers are evaluated; requirements for an optimized receiver are examined.

SURFACE ELECTROMAGNETIC WAVE COUPLING EFFICIENCIES FOR PRISM AND GRATING COUPLING TECHNIQUES - C.A. Goben, M. Davarpanah, T.D. Pickett, M.E. Cerulo, A.K. Singh, D.E. Brandon, University of MO - Rolla, 65401. The excitation efficiencies for the excitation of surface electromagneti waves (SEW) on railroad rail surfaces have been studies experimentally in the microwave frequency range using two optical coupling techniques, the prism and the grating coupling techniques. The excitation efficiencies were measured as functions of frequency, vertical displacement of the coupler above the rail, horizontal (lateral) displacement of the coupler from rail center and pitch, roll and yaw angles of the coupler. The maximum excitation efficiency of the prism coupling technique at 12 GHz. The SEW coupling efficiency curves show a strong dependence on displacement, and pitch, roll and yaw angles.

EXCITATION AND PROPAGATION OF SURFACE ELECTROMAGNETIC WAVES (SEW) ON WATER - A.K. Singh, M. Davarpanah, C.A. Goben, University of MO - Rolla, 65401. The two optical coupling techniques, prisms and gratings, were used for coupling SEW onto water in the microwave frequency range. Coupling was also achieved by using horn antenna direct coupling. The coupling efficiencies at 9 GHz were 70% for horn antenna direct coupling, 15.2% for the prism coupler and 7.5% for the grating coupler; all show a strong dependence on vertical displacement above the water surface. By changing the pitch angle of the prism coupler, the coupling efficiency was increased by approximately a factor of five. By spreading oil on the water, a decrease in received SEW power was noticed. Experiments conducted to detect icebergs were successful. The transmitted and reflected SEW power was measured with flat metallic obstacles. Similar measurements along with scattered radiation measurements were taken for a cylindrical obstacle.

THE MXO, A NEW TYPE CLOCK OSCILLATOR, D.E. Newell, Northern Illinois University, DeKalb, 60115. A crystal oscillator can be generated using a coupled monolithic quartz resonator and a solid state inverter The circuitry can be hybridized readily, creating a stable, small, clock for microprocessors, computer peripherals, or any digital applications. The paper discusses the construction and characteristics of a new type of digital clock oscillator. The oscillator utilizes a coupled dual quartz monolithic resonator and T^2L gate biased as a linear inverter. The circuitry utilizes only four components, two resistors, a quartz monolithic resonator, and a T^2L gate, all of which can readily be hybridized into an integrated circuit configuration. The MXO, Monolithic Crystal Oscillator, provides a clock frequency stable to a few part per million. The output is a square wave with a 50% duty cycle. One of the main features of the MXO is its simplicity which results in a production cost of approximately $5.00. Design and construction details will be discussed in addition to the test results on many MXO's.

BASIC PROCEDURES IN CIRCUIT BOARD DESIGN FOR MICROPROCESSOR SYSTEMS - T.D. Pickett, M.E. Cerulo, C.A. Goben, Engineering Research Center and Electrical Engineering Department, University of MO - Rolla, 65401. A procedure for design and implementation of the Central Processing Unit (CPU) circuit board for a microprocessor based system is developed from basic system consideration. This step-by-step analysis and evaluation can be used by a designer to help make decisions regarding complexity and scope of his entire microprocessor system.

TRANSMISSION LINE ANALOGUE OF TRANSFERRED ELECTRON AMPLIFIERS AND OSCILLATORS, C.E. Kang, Northern Illinois University, DeKalb, 60115. Since the Gunn Effect was found in 1963, the transferred electron mechanism of some semi-conductors such as GaAs, InP, CdTe and InSb has attained a considerable focus in the generation and amplification of microwave and millimeter wave signals. It is the purpose of this paper to derive the equivalent electromechanical representation of transferred electron devices (TED) and to investigate the instability characteristics of the carrier waves in solids by using the equivalent representation Theoretical equivalent representation for TED is attempted and the results are compared with computer calculation and empirical data. The feasibility of wave amplification in TED is also aimed, leading to a carrier description of Gunn Instability. The analysis is good agreement with the empirical results, which confirm the validitv of this model

A TIME SHARED COMPUTER SYSTEM WITH RADIO INTERFACED PERIPHERALS - L.V. Lammert, H.J. Pottinger, Electrical Engineering Department, University of MO - Rolla, 65401. The design of a time-shared computer system with peripheral terminals interfaced over radio data links is treated with application to the minimum budget system. The system will provide access to a computer system for a number of users at a minimal cost to the individual user. Applications include use of a system by users without telephone data link capability. The original design incorporates the radio links in the frequency bands of the Amateur Radio Service with standard Morse Code communication.

POLITICAL SCIENCE FOR THE ENGINEER, R.L. Carter and D.R. Liljegren, University of MO-Columbia, 65201. The course "Engineering Problems in State Legislation" attempts to cultivate student interest in interacting with representatives in government. Though obstacles posed by conflict of interest and campaign finance restrictions have depleted the ranks of legislators with engineering backgrounds, engineering activism can insure that the point of view of those with technical training is represented. Complementing the background of general knowledge of the political process, the course emphasizes items of legislation affecting the practice of engineering. Particular items of interest are followed through introduction, assignment of committee, amendment and passage or death. The role of lobbying by interested groups is described by professional lobbyists, and by legislators. Individual field projects are defined and results described in presentations at term conclusion.

THE NEED FOR TECHNICAL EDUCATION DESIGNED TO MEET SPECIFIC INDUSTRIAL NEEDS, Robert Woll, Moraine Valley College, Palos Hills, 60465. Because of the rapid change and advancement of industrial instrumentation and processes, technical employees are often found in need of further continuing technical education. This presentation deals with identifying and meeting their needs. Often times no program exists in an educational institution and certain workshops or 'short courses' must be developed. The contribution to such efforts afford the teacher of technical and engineering courses with interesting opportunities. The author will outline examples and describe planning and implementation of such programs.

EVALUATION OF LANDSAT IMAGERY FOR MINED LAND STUDIES - Lee Whitebay and David J. Barr, University of MO - Rolla, 65401. The increased concern for the environment coupled with a growing need for natural resources has produced a dilemma. It is impossible to mine coal or any other commodity without disturbing the land. Landsat imagery provides an inexpensive, relatively accurate means for inventorying and monitoring mining activity. Reclamation efforts can be evaluated and mining progress charted at minimal costs to the user.

HIGH PRESSURE STEAM GENERATION BY SOLAR ENERGY, C.E. Moeller, Black & Veatch, Kansas City, MO 64114. A general discussion is given on the generation of steam by solar energy in the past and the future. The current ERDA program for developing a 100 megawatt electric central steam power plant for operation in the mid 1980's is described as the impetus for construction of Solar Thermal Test Facility at Albuquerque, New Mexico. Described are the solar energy collection and redirection by heliostats and solar energy absorption by test receivers in which 2000 psig, 960°F steam can be generated either continuous or intermittent steam flows throughout the sunlit hours of a winter, spring, or summer day.

SOME APPLICATIONS OF COMMON HOUSEHOLD ITEMS IN DENTAL TOOL INNOVATIONS, Gregory S. Jacob, Pre-dental Students Society, University of Illinois, Urbana, 61801. Some common items found around the house can be incorporated into new dental care devices or higher technical value. Over two different devices are created out of objects like a food storage bag, stereo turntable tonearm, and toy racing car motor. The ease of innovation of dental tools demonstrates the accessibility of potential inventors. Each device is presented as a problem-answer.

THE EFFECT ON SHRINK FITS OF FRICTION BETWEEN THE SLEEVE AND SHAFT, Randall Noon, Bonner Springs, KS, 66012. The usual equations for shrink fits assume zero longitudinal stresses. The effects of friction between the sleeve and shaft, and simple constraint are examined using Hooke's Law as a basis for derivations. When friction is considered, significant states of triaxial stress are indicated which can influence failure criteria. When the sleeve and shaft bind, longitudinal strain is zero.

PLASTIC FLOW AND SUBSEQUENT YIELD SURFACES IN CYLINDRICAL TUBES WITH PRESTRAINING, R.L. Pendleton and J.A. Kristiansen, SD School of Mines and Technology, 57701. An investigation has been performed in order to determine the stress distribution in a partly plastic cylindrical tube by subjecting the tube to axial tension or compression and internal fluid pressure. A finite element program was used for comparison of results. Experiments were conducted on thin-walled cylindrical steel tubes to investigate initial and subsequent yield surfaces. Experimental considerations have also been given to the investigation of initial yielding and subsequent yield. Thin-walled cylindrical tubes were subjected to internal fluid pressure and an independent axial force. Initial yield curves were constructed using a small strain offset yield definition for two quadrants in principal stress space. Subsequent yield curves in the same stress space were obtained following a loading into the plastic range.

ORGANO-CERAMIC MATERIALS ENGINEERING TECHNIQUES FOR PERFORMANCE ENHANCEMENT OF ELASTOMERS, B.K. Sarkar, M.K. Mukherjee, Vikram Sarabhai Space Centre, Indian Space Research Organization, Trivandrum-695022. The role played by various types of elastomers for relevant applications have been enumerated. An analysis reveals that while these materials have, among others, excellent thermal stability as well as sealing properties there is enough scope for improving their mechanical characteristics. To this effect the critical involvement of ceramic based materials mainly as fillers have been brought out. The interface between such fillers and elastomeric matrix has been elaborately dealt with in order to reveal the mechanism for controlling the mechanical properties for the purpose of utilization enhancement of the elastomers. The indispensable contribution of software/anticipation engineering to design such high performance elastomers is also pointed out.

ENVIRONMENTAL SCIENCE

THE EFFECTS OF PHTHALATE ESTERS ON GEOCHEMICAL CYCLES IN FRESHWATER HYDROSOIL, R. C. Mutz and J. R. Jones, Forestry, Fisheries and Wildlife, Univ. of Missouri, Columbia, 65201. Di-2-ethylhexyl phthalate (DEHP), a widely used plasticizer, has been found as an environmental contaminant in fish and water samples. Studies were conducted in intermittant flow-through hydrosoil microcosms to determine whether this compound interfered with the following microbial processes: nitrification, ammonification, sulfur reduction, protein digestion, amyolytic activity, and ^{14}C glucose-$^{14}CO_2$ mineralization. DEHP, and its degradation products, 2-ethylhexanol and phthalic acid, were applied to the hydrosoil at concentrations of 1 and 100 mg/l. The MPN method was used in conjunction with differential media to quantify the microorganisms associated with each process. The compounds tested produced no significant effects either through a reduction in numbers or a suppression in physiological activity of the microflora. Shake-flask studies evidenced some stimulatory effect on nitrification, but sulfur oxidation and ammonium production were equal to that in the untreated samples.

VARIOUS CHEMICAL AND PHYSICAL FACTORS WHICH INFLUENCE THE BIODEGRADATION OF DI-2-ETHYLHEXYL PHTHALATE (DEPH) IN HYDROSOIL, T. D. Fish and B. T. Johnson, Forestry, Fisheries and Wildlife, Univ. of Missouri and Fish-Pesticide Res. Lab., Columbia, 65201. Nutrient cycling in freshwater is influenced by oxygen tension, redox potential (Eh), pH, and temperature. These parameters also influence the biodegradation of environmental contaminants. We found degradation of DEHP, a major plasticizer found as an environmental contaminant, is affected by altered Eh potential. Both in hydrosoil samples and in pure culture bacterial experiments with hydrosoil isolates, positive Eh potential and available oxygen favor the degradation of DEPH. MPN analysis with differential media showed significant increases in the physiological activities and total population of the microflora during in vitro experiments, but none were attributed to Eh manipulation. Principle metabolites, mono-2-ethylhexyl phthalate and 2-ethylhexanol, showed possible inhibitory effects on the degradation of DEHP. Radiorespirometer studies indicated ultimate biodegradation to CO_2.

IN-SITU MEASUREMENTS OF SEDIMENT OXYGEN DEMAND IN ILLINOIS STREAMS AND LAKES, Thomas A. Butts, Illinois State Water Survey, Peoria, 61601.
Sediment oxygen demand (SOD) rates have been measured in the field using equipment and techniques designed and developed by the State Water Survey. SOD due to benthos activity has generally been neglected by most water quality modelers. Using a bell chamber to entrap and seal off a known quantity of water over a given area of bottoms the drop in DO concentration is measured and converted to areal rates in terms of $g/m^2/day$. In-situ rates have been measured at 135 sites in various lakes and streams. Values up to 25 $g/m^2/day$ have been recorded. SOD has been found to be a significant contributor to oxygen depletion in streams.

UPTAKE OF SELECTED AMINO ACIDS FROM SEA WATER BY SPAT OF OYSTER, Crassostrea gigas, George J. Schulte and Addison L. Lawrence, Northeast Missouri State University, Kirksville, 63501. Oyster spat (juveniles) were tested for ability to remove amino acids from sea water. Animals were incubated, under different experimental conditions, in artificial sea water solution containing certain labeled amino acids. Uptake was determined using radioisotopic methods. Results showed spat accumulated into their tissues against apparent concentration gradients amino acids from sea water. Uptake was specific, energy dependent, and saturable. These results support the presence of a metabolically linked carrier-mediated uptake mechanism for amino acids in spat of C. gigas. This further suggests the importance of dissolved organics to nutrition of developing marine bivalves both in laboratory culture and the natural environment. (Supported by NIH Grant FD-00546-01).

RELATIVE IMPORTANCE OF FOOD AND WATER SOURCES TO CADMIUM UPTAKE BY Gambusia affinis (POECILIIDAE), David R. Williams and John P. Giesy, Jr., Drury College, Springfield, 65802. The relative importance of food and water as Cd sources to the mosquitofish, Gambusia affinis, was studied in a factorially designed experiment with two levels of Cd in food and water after 2, 4, 6, and 8 weeks of exposure. There was significant Cd uptake from water but no significant uptake from food except after 8 weeks in the presence of Cd in water. When exposed to a continuous flow of 10 µg Cd/l in water, G. affinis did not reach equilibrium Cd concentrations after 8 weeks.

CHRONIC EFFECTS OF TWO PHTHALIC ACID ESTERS ON MIDGE CHIRONOMUS PLUMOSUS, J. M. Streufert and H. O. Sanders, Forestry, Fisheries and Wildlife, Univ. of Missouri, and Fish-Pesticide Res .Lab., Columbia, 65201. The phthalate acid esters (PAEs) di-n-butyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) are plasticizers and both chemicals are considered environmental contaminants. Larvae of the midge Chironomus plumosus were chronically exposed to DEHP and DBP concentrations ranging from 180 to 560 µg/l. First instar larvae were placed in flow-through diluter systems which employed hydrosoil as a substrate. After 30 days, approximately 70-90% of the larvae had emerged. Exposure of larvae to DBP and DEHP through a complete life cycle did not significantly ($P < 0.05$) reduce emergence. Emergent adults were allowed to mate within the screened aquaria, which provided eggs for the hatchability study. While DBP did not significantly reduce egg hatchability, preliminary tests with DEHP indicate the possibility of some inhibition in hatchability.

DISTRIBUTION AND MOVEMENTS OF FISHES IN A SMALL STREAM, Jon Duyvejonck, Illinois State University, Normal, 61761. The effects of dredging upon a small stream are studied with regard to species composition. The species composition in an undredged section is compared to a dredged section. Samples were taken every two weeks from August through mid-November. Fish movements in the study area were also studied by a mark-recapture method using freeze branding. Recaptures were made two weeks after marking. The distance from the original release site was recorded for each species. Evidence suggests that dredging disrupts habitat favored by some species and that they do not readily return to such areas. Recapture of marked fishes indicates that they exhibit little fall movement, but there appears to be a slight downstream movement.

RELEASE AND FERTILIZATION OF BLACK WALNUT (Juglans nigra) IN SOUTHWEST MISSOURI, Phillip E. Graf and H. E. Garrett, School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia, 65201. Black walnut diameter growth is significantly increased by release and foliar fertilization. During the summer of 1976, five foliar applications of NZN (Allied Chemical Co. - 22%N, 5.5%Zn) in combination with mechanical release significantly increased stem growth at a height of 2.8 m but not at 1.4 m in a natural, 37-year old stand of black walnut. Growth at 1.4 m was, however, significantly greater in released than non-released trees with no discernible effect from fertilization. Overall growth responses were greater on a drier intermediate upland site (site index [S.I.] for walnut - 55) than on an upland bench site (S.I. for walnut - 85).

HEMATOLOGICAL RESPONSES OF THE FERAL BURRO, Equus asinus--FIELD AND LABORATORY. T.P.Davis, M.K.Yousef, C.L.Douglas, J.D.Stockman III and H.D. Johnson, Univ. of Nevada, Las Vegas and Univ. of Missouri, Columbia, 65201. Hematological parameters on a feral population of 28 male and 13 female burros captured in Death Valley, California, were compared to four burros from the same herd under extensive study at the University of Missouri, Columbia. There was no significant ($P > 0.10$) difference due to sex in any of the parameters studied and no significant ($P > 0.10$) difference was observed in mean hematocrit, hemoglobin, red blood cell count total, serum protein or white cell differential count. The ratio of Hb/Hct was 0.27 in the field population which is significantly ($P < 0.05$) lower than the laboratory study (0.35). Based on these data, hematological studies on blood samples taken in the field are quite comparable to laboratory studies but the ranges of the blood values for the field population were very broad. This was due to the stress of restrainment in the field as equines have muscular spleens. (Supported by N.P.S. Contract #CX800040014)

CONCENTRATION OF TOTAL ESTROGENS IN THE SERUM OF CYCLING, PREGNANT, AND LACTATING GUINEA PIGS, David M. Early and Ralph R. Anderson, University of Missouri, Columbia, 65201. Blood samples were obtained from 4 to 13 guinea pigs per group during stages of the estrous cycle, pregnancy, and lactation; and concentrations of total estrogens in serum were determined by radioimmunoassay. Estrogen in serum rose nonsignificantly from midcycle (27.4 ± 17.6 pg/ml) to the day of estrus (52.8 ± 13.6 pg/ml). Levels during pregnancy rose slowly from day 20 (13.2 ± 4.7 pg/ml) to day 40 (34.4 ± 5.6 pg/ml) and more rapidly to day 60 (153.9 ± 25.6 pg/ml). On the day of parturition (day 1 of lactation) estrogen concentration was very low (18.1 ± 11.5 pg/ml) but a dramatic increase was observed on day 2 of lactation (144.7 ± 48.4 pg/ml). None of the animals were rebred and a return to midcycle levels (0.12 ± 0.12 pg/ml) was observed on day 5 of lactation followed by another proestrus peak (120.1 ± 75.6 pg/ml) on day 15 of lactation.

SLEEP DISTURBANCE FROM ENVIRONMENTAL NOISE, E. Margaret Acre and Marilyn Rubin, St. Louis University, St. Louis, 63104. This study was done to determine the effect of environmental noise on the subjects' ability to sleep while hospitalized on intermediate care medical-surgical nursing units. Sound samples (N = 1,152) were collected continuously over twenty-four hours. A population of 1,188 subjects participated in the study. Significant differences (P = .05) in the variance of subjects' statements of inability to sleep (per capita) were found between noise levels; between hospitals samples; between subject categories; and between subject categories and noise levels. Sound level which interrupted sleep was at or above 39 dB Leq.

HYPERTHERMIC EFFECTS OF LOW-INTENSITY ULTRA SOUND IN RATS. Spencer R. Bowers, St. Louis University.

ZINC TOXCITY OF THE BLUE GILL (Iopomis macrochirus) R.D. Salee[1], R.E. Sparks[2], C.M. Thompson[2] and D.A. White[1], Western Illinois University, Macomb, Illinois, 61455 and Illinois Natural History Survey[2], Havana Illinois, 62644. A test was conducted at the Illinois Natural History Survey Field Headquarters in Havana, Illinois using immature bluegill (ave. live weight 3.15g, length 6.0cm) as test organisms to determine the toxicity of zinc. Normal flow through bioassay techniques were followed throughout the test. Water hardness was 247-263 mg/l as calcium carbonate and total alkalinity was 218.9 mg/l as calcium carbonate. Lethal concernations to 50% of the bluegill (LC 50's) were determined graphically. The 96 hour LC 50 was 15.2 mg/l and a suitable vertical asymptote for a lethal threshold concentration to 50% of the bluegill (LTC50) was reached in 168 hours. The LTC 50 was 14 mg/l. These values are well above zinc levels in most aquatic systems at the present time. However, bottom sediments act as a sink for zinc and other heavy metals, and could present a problem in the future.

SELECTIVE FEEDING BY TWO AQUATIC SNAILS ON THE LEAVES OF SHINGLE OAK, SILVER MAPLE, AND BLACK CHERRY, Richard K. Mud and D.A.White, Western Illinois University, Macomb, 61455. Investigations on the feeding habits of snails, (Helisoma trivolvis, and Physa gyrina) on oak (Quercus imbricaria), maple (Acer saccharinum), and cherry (Prunus seratina) revealed marked selection. When snails were isolated and allowed to feed upon 1 cm. leaf disks of cherry and oak in petri dishes, the snails consumed 67.6 to 97.3% of the cherry leaf disks and 4.1 to 23.5% of the oak leaf disks. When a group of snails were allowed free choice to feed on whole oak, maple, and cherry leaves that were strung across a tank (100 cm x 60 x 12 cm) so that they hung in the water for five days, 12.7 to 14.2% of the oak leaves, 48.3 to 66.4% of the maple leaves, and 60.6 to 92.6% of the cherry leaves were consumed. Amount eaten by the snails depended upon the amount of food available to them previous to the experiment. Results of the experiment show that both species of snails definitely prefer cherry leaves to oak leaves, and that they prefer cherry somewhat more than maple leaves.

BEHAVIOR OF MARITIME COARSE AEROSOL IN DEPENDENCE OF AIR STABILITY, Josef Podzimek, University of Missouri-Rolla, Rolla, 65401. The aerosol distribution above the seashore of southern Texas is investigated on the basis of the three series of flights performed with instrumented aircraft in May, 1975. Concentrations of particulates larger than 0.5 μm were recorded by an optical counter and NaCl particles, collected in the cascade impactor, were analyzed in an optical microscope. During adiabatic conditions, the concentration of particulates decreased in accordance with the exponential law. On the temperature inversion layer the large and giant particulates behaved differently depending on the depth and altitude of the inversion. An attempt is made to explain this observation.

ANALYSIS IN WONDERLAND: THE ACADEMIC AS ENVIRONMENTAL CONSULTANT--A BUSINESS POINT OF VIEW, Gary H. Richins, Burns & McDonnell, Kansas City, Missouri, 64141. The problems encountered by business when members of the academic community are engaged as environmental consultants are discussed. The rationale behind engaging a consultant and the dilemma of research versus reality is examined. Specific problems such as inexperience in preparing environmental reports, lack of familiarity with governmental policy, identifying and limiting the scope of work, meeting project deadlines, consulting versus academic committments, and representation at public hearings are discussed. Possible solutions include increased use of proposals, more strict interpretation of contracts, improvement of communications and finite limitations of scope of work

COMPOSITION OF THE PRESETTLEMENT FORESTS OF THE "UNGLACIATED" JO DAVIESS HILLS OF NORTHWESTERN, ILLINOIS. M. T. Jackson, Indiana State University, Terre Haute, 47809. Forest composition was determined for the Jo Daviess Hills region by analysis of the General Land Office Survey Records of 1842. Upland slope forests (86% of the area), with 21 species, were 97% oak-hickory, with white, bur and black oaks the leading dominants. Ravine forests (7% of area) were more mesic (19 species), with bur oak, elm, basswood, plus black and white oaks the dominants. Terraces (2% of the area) had only 8 species and were 95% oak-hickory. Mississippi River floodplain forests (5% of area), with 13 species, were dominated by hydrophytic soft maple, elm, river birch, ash and black willow. These data suggest that the original vegetation of the Jo Daviess Hills was predominantly oak-hickory, rather than maple-basswood as traditionally mapped.

RARE AND ENDANGERED VERTEBRATES OF ILLINOIS, Richard H. Thom, Illinois Nature Preserves Commission, Rockford, 61103. This paper discusses the methodology and terminology for development of a state list of the Endangered, Vulnerable, and Rare Vertebrates of Illinois with brief comments on the status of some species. A proposed inventory of Illinois' rare and endangered species is discussed and the state of the knowledge reviewed. Recommendations are presented for a comprehensive program on Illinois' rare and endangered species.

EARLIEST BLOOMING DATES OF SOME COMMON TREES IN THE PEORIA AREA. Irene M. Cull, 803 N. Ashland, Peoria, IL, 61604. The purpose of recording blooming dates of trees in this area was to learn when blossoms may appear and the effect of temperature on the earliest blooming dates of various species. The earliest dates on which flowers were observed on 40 species of trees were recorded during 26 years in Peoria. These data were tabulated and the average and range of earliest blooming dates for each species were determined. Highest temperature before blooming date and highest and lowest temperature on blooming date were tabulated. Temperature has the greatest effect on the earliest flowering species. Silver maple bloomed earliest, and basswood latest. Sudden high temperature hastened flowering, while a sudden cold spell delayed it. It is possible to predict the earliest flowering dates of the various species on the basis of temperature.

GEOGRAPHY

First Session
April 1-2, 1977 at the University of Missouri-Columbia

CHANGING LAND USE PATTERNS IN THE PAST TWENTY YEARS IN DOUGLAS COUNTY, MISSOURI, Dale Coble, University of Missouri-Columbia.

SPREAD OF IRRIGATION IN MISSOURI, 1945-1977, Mark Ford, University of Missouri-Columbia. This paper deals solely with the spatial distribution and growth of irrigation in Missouri. The factors responsible for the astounding growth in irrigation are many and varied and will be examined. Future projections are made on the basis of present and historical data. By 1950 the advantages of irrigation clearly outweighed previous misconceptions as seen by the rapid adoption of irrigation by area farmers and the corresponding acreage increases.

THE REFORMA OIL FIELDS OF MEXICO, Albert J. Grabow, Crowder College, Neosho, Missouri.

AN INTRODUCTION TO MISSOURI'S NRIS: A PILOT DEVELOPMENT PROJECT, Michael Hartmann, Missouri Department of Natural Resources, Jefferson City, Missouri.

BONNOTS MILL: A CASE STUDY OF CHANGING LAND USE, Shashi Krishna and William Thompson, Lincoln University, Jefferson City, Missouri.

COLONIZATION: AN EDUCATIONAL EXPERIENCE OF COLONIZATION OF THE NEW WORLD, Mark Mills and John Marvin, Rock Bridge High School, Columbia, Missouri.

CHANGE IN SETTLEMENT PATTERNS IN WHITE OAK TOWNSHIP, HARRISON COUNTY, MISSOURI, 1876-1977, Mary Price, University of Missouri-Columbia.

THE CHANGING SCALE OF HUMAN ACTIVITY IN WASHINGTON COUNTY, MISSOURI: A TECHNOLOGICAL APPROACH TO HISTORICAL GEOGRAPHY, Harry Styron, University of Missouri-Columbia.

SOME APPLICATIONS OF GEOGRAPHY IN COUNTY PLANNING, John Whiteside, Boone County Office of Planning and Zoning, Columbia, Missouri.

Second Session
April 29-30, 1977 at the University of Missouri-St. Louis

DISTRIBUTION OF SOME PLANT AND ANIMAL TOPONYMS IN MISSOURI, Kim Beaudoin, Leominster, Massachusetts 01453. Toponyms (place names) of seventeen plants and animals have been mapped for Missouri. Source for the toponyms is the comprehensive card file of the Ramsey place-name collection at the University of Missouri. Toponyms mapped are pine, cypress, beech, maple, sycamore, cherry, cedar/chicopee, elm, bear, buffalo/boeuf, panther, elk, wolf, turkey, eagle, laurel, and cotton. From a comparison of these toponymic distributions with known nineteenth-century distributions of the plants and animals, it is concluded that some are apparently good indicators of historical distributions, but others are not so good.

THE EFFECTS OF ORDER NO. 11 ON BATES COUNTY, MISSOURI, David J. Henson, University of Missouri-Columbia. In August 1863 Union General Thomas Ewing issued Order No. 11. With it came an instant legacy of infamy and hatred along with mass evacuation in Missouri counties along the Kansas border where it was believed the Missourians were lending grassroots support to Quantrill's Confederate guerillas. The effects of this emigration were absolutely devastating as an entire region was left all but empty. For nearly two years Bates County was virtually uninhabited. The ramifications of this episode on that county and its economy provide us with an unusual perspective on a truly unique and tragic event in America's past.

COFFEE--NUMBER TWO--TRYING HARDER, Ray Rouse, Rosenthal and Company, San Rafael, California.

DISPERSAL OF A MISSOURI GERMAN-IMMIGRANT FAMILY, 1847-1966, Walter A. Schroeder, University of Missouri-Columbia. Rural immigrant groups in the Midwest have been generally characterized as "locationally stable." This study of a large, nineteenth-century German-immigrant family to Missouri elaborates upon that generalization by concluding that during the initial years of settlement a significant proportion of immigrants had a loose attachment to a specific location; that while stability may have been characteristic of the group, it was less so of individuals within the group; that later generations of the family fell quickly into the mainstream of American mobility.

DISTANT-PROVENANCE, PLEISTOCENE LOESS DEPOSITION IN WEST-CENTRAL ILLINOIS: A POSSIBLE CONTEMPORARY ANALOG, Thomas K. Van Heuklon, Western Illinois University, Macomb, Illinois 61455.

RAPID FRACTIONATION OF PHOSPHATE IN ANTHROSOLS, William I. Woods, Southern Illinois University, Edwardsville, Illinois 62026.

GEOLOGY-GEOPHYSICS

PETROLOGY OF THE WINTERSET LIMESTONE (PENN.), JACKSON COUNTY, MISSOURI, Susan V. Eubank, University of Missouri-Columbia, 65201. In order to provide additional information concerning the stratigraphy, environments of deposition, and diagenesis of the Winterset Limestone, a petrographic study of exposures in Jackson County, Missouri was undertaken. Six major rock types which are believed to reflect nearshore sedimentation are: brachechino, oolitic lime, wackestone with phyloid algae, mixed fossil-algal lime wackestone, molluscan-brachiopod lime wackestone, mixed oolitic lime grainstone, and mixed lime wackestone-lime mudstone. Cross beds, in the oolitic facies exhibit a primary mode of 53° and an average dip of 27°. The majority of the carbonates are calcitic. Some recrystallization to coarser crystalline calcite is in evidence. Dolomite, which is rare, occurs both as silt-size, subhedral to euhedral crystals that have replaced fine-grained calcite matrix and as void-filling cement within some ooids. Silicified skeletal grains and matrix are common.

PETROLOGIC EXAMINATION OF CHONDRULES FOUND IN THE WESTON, ALLEGAN, AND GUERANA STONY METEORITES, Paul P. Sipiera and Stephanie C. Stauner Harper College, Palatine, IL 60067. Most stony meteorites contain varying amounts of small, spherical objects known as chondrules. These chondrules are believed to represent primitive material formed during the early cooling stages of a solar nebula. Van Schmus and Wood (1967) utilized the textural features of chondrules, combined with bulk mineral compositions, to develop a means for classification of stony meteorites. Their system also implies a genetic relationship between certain types. The Weston, Allegan and Guerana stones have been classified as H_4, H_5, and H_6 petrologic types respectively. In this study, these meteorites will be examined to evaluate possible genetic correlations as indicated by the textures of the chondrules present.

STRUCTURAL AND HYDROLOGIC STUDY OF THE ROUBIDOUX SANDSTONE, ST. JAMES-CUBA AREAS, MISSOURI, Alan L. Davis and Michael A. Bryant, University of Missouri-Rolla, Rolla, 65401. Data from 350 water well logs were studied for stratigraphic, structural and hydrologic information. The Ordovician Roubidoux Sandstone, aquifer of special interest, ranges in thickness from 75 to 175 feet within the 200 square mile area studied. The formation crops out locally and extends to depths of 200 feet or more. Composition is predominantly quartz sand with some dolomite and cherty layers. Two to three members of the formation are identifiable. Folds of several miles strike length, to 6 miles wave length and 200-foot amplitude trend northwesterly. The Cuba fault parallels an eastern fold and loses structural expression west of Cuba. Static water levels and varying flow rates follow the general trend of the folds and are correlated with a middle sandstone member.

A MULTIVARIATE STATISTICAL STRATEGY FOR USE IN ENVIRONMENTAL ASSESSMENTS, Peter H. Feldhausen, Dames & Moore, Park Ridge, 60068. Cluster analysis, ordination and discriminant analysis when applied sequentially to benthic data obtained at the site of a proposed LNG facility is shown to be an effective strategy for quantifying environmental relationships and in the preparation of environmental assessments. R-mode cluster analysis was used to define two major species associations, onshore and offshore. Samples obtained at the location of the facility and at control stations down coast were partitioned into 4 environmentally significant classes with Q-mode cluster analysis. Discriminant analysis showed the classes to be statistically distinct and was used to identify those species most useful for discriminating among the 4 classes.

SHOCK METAMORPHISM (?) IN THE PRECAMBRIAN GRANITE PEGMATITE AT THE DECATURVILLE STRUCTURE, MO., Douglas C. Melton, Jr., University of Mo.-Rolla, 65401. The Decaturville structure, a 6 km wide polygonal feature, is located 24 km north of Lebanon, Mo. in Camden-Laclede Counties. Local structure, geometry, and the presence of shatter cones suggest that the structure is an astrobleme. The Precambrian core of the structure, which probably represents a detached basement block, was mapped, sampled and petrographically analyzed. The core rock is granite pegmatite composed of perthitic microcline, quartz, and muscovite with accessory apatite, tourmaline, xenotime, biotite, magnetite and calcite. Examination of thin sections reveal a lack of definite shock metamorphic features in the granite pegmatite in contrast to the presence of shock metamorphism in surrounding lithologic units. The absence of shock features and depth to basement portend a source of shock waves from above, with shock intensity decreasing with depth.

LOWER PALEOZOIC MARGINAL BASIN-ISLAND ARC ASSEMBLAGES FROM NORTHERN APPALACHIANS, H. D. Upadhyay, Northeastern Illinois University, Chicago 60625. New stratigraphic and petrochemical data from the Lower Ordovician ophiolites of Newfoundland shows that they represent the crust of marginal oceans and related island arcs rather than the main Proto-Atlantic itself, as commonly believed. The overlying repetitive pillow lava and pyroclastic formations, the latter with andesitic agglomerate and volcaniclastics, are also typical of some of their modern analogues in the Circumpacific Belt, and might have formed by the intermittent subduction of the Proto-Atlantic Ocean. Major and trace elements of the ophiolities show compositions in the range of calc-alkaline to island arc tholeiites. The presence of sheeted dykes in these indicates that the marginal basins, both ancient and modern, must have formed through spreading, although perhaps not along well defined ridges.

FIRST SURFACE OCCURENCE OF THE BLACKROCK FORMATION IN MISSOURI. Michael Fix, University of Missouri-St. Louis, 63121. Outcrops of the Early Ordovician Blackrock Formation were recently discovered in southeastern Missouri. The Blackrock is latest Early Ordovician age, and was previously known only from subsurface cores and outcrops in north central Arkansas and in subsurface cores from southeastern Missouri. The Blackrock in Missouri is a silty, slightly arenaceous, medium to thin bedded dolostone containing an abundant and distinctive fauna. This fauna, which has a low diversity, consists of brachiopods, cephalopods, a rostroconch mollusc, trilobites, and a diagnostic--- coral-like colonial organism of uncertain affinities. The stratigraphic position and affinities of the Blackrock are currently under debate, and some recent evidence strongly indicates that it is a lateral facies of the Smithville Formation, rather than overlying it, and in turn the Smithville Formation may be a facies of the supposedly underlying Powell Formation.

DISSOLVED SALTS IN DEEP WATER WELLS--BATES, VERNON, AND BARTON COUNTIES S.W. MO., James M. Darr and Alden B. Carpenter, University of Missouri-Columbia, 65201. In the years 1966 through 1975 the concentration of dissolved salts has been increasing in the city supply wells of Rich Hill, Hume, Bronaugh, Nevada, Moundville, Liberal and Mindenmines, of Bates, Vernon and Barton counties, MO. This correlation has been established by examining the increase in chloride ion concentration with time. Data were obtained from public records of water supply district wells, and from sampling by the authors. Through statistical analysis of the data, it was determined that the following 95% confidence intervals can be placed on the rate of chloride ion concentration increase, in mg/1/yr:, for these wells: Hume, 44 ± 17; Rich Hill, 12 ± 6.1; Bronaugh, 39 ± 15; Nevada, 2.8 ± 2.5; Moundville, 19 ± 8.3; Liberal 6.7 ± 1.0; Mindenmines, 4.0 ± 2.7. Pumping of the Paleozoic aquifers in southwest Missouri has resulted in falling groundwater levels, causing an influx of brackish groundwater out of eastern Kansas into Bates, Vernon, and Barton counties.

HIGH-ANGLE FAULTS IN JACKSON COUNTY, MISSOURI, Richard J. Gentile, University of Missouri-Kansas City, 64110. Gomer Jenkins Jr. and Robert McMillen, Missouri State Highway Department, Kansas City, 64128. Several high-angle, normal faults were exposed during construction of a two kilometer segment of Interstate Highway 470 about 15 kilometers southeast of downtown Kansas City. The faults strike northwest and a vertical slip of 2 meters is common. Faults of similar dimensions have been recognized at nearby mining operations of the Bethany Falls Limestone Member, a rock unit that is being exploited commercially at an increasing rate as the City expands into undeveloped areas. The faults occur on small folds of no more than a few square kilometers in area. These small folds are present on northwest-southeast trending structures of regional extent and may be caused by block faulting of the Precambrian basement rocks. Local structure should be taken into consideration when determining the subsurface geology at proposed mine and construction sites.

MINERALS OF ILLINOIS - FUTURE CHALLENGES, Jack A. Simon, Illinois State Geological Survey, 61801. Illinois is richly endowed with mineral resources in addition to fertile soil and abundant water. Coal and oil and gas resources will contribute importantly to meeting future energy needs. Illinois has produced also fluorspar, galena(lead), sphalerite((zinc), limestone, sandstone, silica sand, tripoli, sand and gravel, and minor amounts of other minerals.

Our civilization is based on availability of minerals. Recent public awareness of dependence on foreign sources for oil is not matched by similar awareness for many other essential minerals. Future planning will require regard for all non-renewable mineral resources to assure availability to meet national needs. Additional research also is required to develop new sources of minerals including recovery of mineral values from wastes.

A NEW TECHNIQUE FOR SECTIONING FUSULINIDS, J. M. Cocke, Larry Brethower, and David Barney, Central Missouri State University, Warrensburg, 64093. A new process for sectioning fusulinids is described here that is superior to earlier techniques, in that large numbers of specimens can be simultaneously oriented. The technique involves 1) mounting the specimens in partially water soluble glue with axes parallel to the mounting surface, 2) realignment of specimens if disoriented as the glue solidifies, and 3) surrounding and covering the fusulinids with dental plaster that sets with a hardness between 2.5-3.0. At this point, the oriented, embedded specimens are ground to the proloculus with relative ease. Removal from the plaster prior to final mounting of the specimens may be desirable and is accomplished by heat treatment or by coating the specimens with a commercial substance that facilitates their removal.

PRELIMINARY STUDIES ON COALS FROM NORTHWESTERN ILLINOIS, Ronald H. Affolter, Mohan K. Sood and Robert W. Doehler, Northeastern Illinois University, Chicago, 60625. X-ray diffraction studies on the mineral separates of systematically collected coal channel samples for the Fulton-Peoria-Knox counties of Illinois indicate that these coals contain appreciable amounts of mineral matter in the form of clays (illite-kaolinite), gypsum, calcite, silica, pyrite, galena(?) and sphalerite. Spatial distribution of mineral matter and trace elements S, Cu, Pb, Zn, Hg, and Cd will be presented to develop their chemical interrelationships and to evaluate the environments of coal formation with possible impact on coal technology.

RECLAMATION OF REFRACTORY CLAY MINES IN MISSOURI, Robert Ruffner and Wayne Wilkening, A. P. Green Refractories Co., Mexico, MO. 65265. Mining and land reclamation must by necessity be considered and administered as a single operation in order to realize a proposed mining and reclamation program which will result in planned, beneficial, post-reclamation uses. With the aid of proper equipment and planning, mined-land reclamation in Missouri can be achieved utilizing revegetation and water impoundment procedures. Using these techniques, mined lands have become agricultural, industrial, and recreational sites. Unified coordination of refractory clay mining and land reclamation successfully leads to multiple and productive land uses.

TERTIARY STRATIGRAPHY OF THE UPPER RUBY RIVER BASIN, MADISON CO. MONTANA, Ronald A. Riepe, College of Lake County, Grayslake, IL, 60030. The continental Tertiary Bozeman Group occurs as two unconformable, lithologically distinct depositional units. The mostly fine-grained Renova Formation (Early Oligocene to Early Miocene) includes the Climbing Arrow, Dunbar Breek (with Sage Creek Basalt 30.6my ±1.4my and Table Mountain Limestone Beds), and Passamari Members of lacustrine, fluvial, deltaic and alluvial fan origin. The mostly coarse-grained Sixmile Creek Formation (late Early Miocene to Early Pliocene) includes the Maloney Ranch, Ruby River, Greenhorn Mountains, and Snowcrest Mountains (with the Ledford Creek Limestone Bed) members of alluvial fan and fluvial origin.

Cd-Ni IN STREAM-BANK SEDIMENTS AND AQUATIC ALGAE, MERAMEC PARK DRAINAGE AREA, MISSOURI, Paul Dean Proctor and B. Sinha, University of Missouri-Rolla, Rolla, 65401. Sixty nine sample sites in 5 drainage areas were sampled within the 1475 mi^2 Upper Meramec River drainage basin. Acid leachable Cd and Ni were determined for active stream sediments (ASD), bank sediments (BSD) and selected aquatic algae (AA). Average Cd content in ASD ranged from 0.3 ppm to 4.0 ppm, and in BSD from 0.2-1.2 ppm. Ni content averaged from 7 ppm to 26 ppm in ASD and from 9 to 18 ppm in BSD. Cd and Ni in aquatic algae averaged from 0.5-7.1 ppm and 8-98 ppm, respectively. Highest contents of both metals is in the Viburnum-Northern New Lead Belt drainage area. Lowest average metal contents fall within a primitive drainage area. ASD samples generally have higher metal content than older BSD. Higher metal contents in ASD-BSD-AA samples from the Viburnum-Northern New Lead Belt drainage area appear to be related to man's disturbance of original metal patterns.

A DELTAIC-EUSTATIC MODEL FOR PENNSYLVANIAN SEDIMENTATION IN NORTHERN ILLINOIS, Charles Wright Shabica, Northeastern Illinois University, Chicago, Illinois, 60625. It is generally agreed that Pennsylvanian age cyclothems in northern Illinois are deltaic in origin. However, there is little agreement on the specific application of the delta model. Appalachian and European cyclothems have been more successfully interpreted as they often have close modern counterparts. A major difficulty in applying a delta model to the northern Illinois deposits lies in the widespread, continuous, yet thin development of the strata, particularly the coal members. Based on a detailed, unit by unit geologic study, a low energy, low gradient delta model (comparable to a tropical Mississippi delta) coupled with eustatic sea level fluctuations is proposed.

A SPORADOCERAS FROM THE SAVERTON FORMATION OF MISSOURI, A. C. Spreng and David M. Work, University of Missouri-Rolla, 65401. The Saverton Shale is well known to stratigraphers concerned with the Devonian-Mississippian boundary problem in the mid-continent Mississippian type area. Current placement within the Upper Devonian is based solely on conodont faunas. Therefore, the discovery in Ralls County, Missouri of a single Saverton ammonoid referable to Spora-

doceras cf. S. muensteri (von Buch), a cosmopolitan Upper Devonian species previously unreported from North America, is worthy of note. This species is known to extend through Stufe doV of the Western European ammonoid succession; this is consistent with previous conodont correlations of the Saverton.

SOLUTION STRUCTURES IN OZARK CAMBRO-ORDOVICIAN CARBONATES MAY HAVE OFFERED A UNIQUE "PALEOECOLOGICAL NICHE. B. L. Stinchcomb, St. Louis Community College at Florissant Valley. Cambrian and Lower Ordovician Stratigraphic Units of the Ozark Uplift are unique in some features. One of these is the presence of local variations in a generalized model of shallow-water carbonate sedimentation. Local solution structures on the Cambro-Ordovician seafloor produced a local increase in water depth. These can be identified by the presence of local concentrations of monoplacophorans and other mollusks. These concentrations are believed to represent a thanatocoenose associated with stromatolites where the deeper waters offered protection during periods of low tide.

A NEW PLEISTOCENE LAKE DEPOSIT IN WEST-CENTRAL MISSOURI, John W. Emerson, Central Missouri State University, Warrensburg, 64093. Recent field work has defined the western and southern boundaries of a Pleistocene lake deposit in Johnson and Pettis Counties. This deposit, herein called the Whiteman Formation, is south of the glacial margin as delineated by previous studies. Methods of study included field mapping, augering, seismic refraction, and hydrometer analyses. A seismic velocity of 4500-4700 feet-per-second is characteristic of this deposit. The Whiteman Formation is a light gray clayey silt found on uplands at elevations of 800-890 feet. The deposit is up to 35 feet thick and overlies either Pennsylvanian bedrock or Quaternary fluvial gravels. The U.S. Soil Conservation Service has assigned soil formed on the Whiteman to the Haig Series, a type which is not found elsewhere in this part of Missouri. The formation is considered to be of Kansan age and correlative with the Ferrelview Formation of Northwest Missouri.

PHOTOGRAPHIC INVENTORY OF DAMS IN MISSOURI, J. Hadley Williams, Div. of Geol. & Land Survey, DNR, Rolla; Jerry Phelan, U.S. Corps of Engineers, St. Louis, Mo; and David Rath, Tennessee Valley Authority. Loss of life and property caused by dam failures prompted Congress to require a nationwide survey of dams. In Missouri, this was done by the Div. of Geology & Land Survey under the supervision of the Corps of Engineers, St. Louis Dist. Missouri had insufficient data and it was necessary to devise low-cost procedures to inventory dams. The initial phase involved use of LANDSAT I (ERTS-1) imagery. Detailed data were then acquired using aerial photography in conjunction with topographic maps and a mail canvas inventory. Field crews checked some dams to verify inventory data reliability. An area, representative of lake development in Missouri, was selected to statistically test the reliability of the in-house procedures developed for the inventory. A light aircraft was used to survey dams and obtain low-level vertical and oblique color and color infrared aerial photography of each dam. A total of 2315 dams was inventoried by October 1974 at the completion of the statewide study.

RELATIONSHIPS BETWEEN DOLOMITE COMPOSITION AND THE DISTRIBUTION OF SULFIDE MINERALIZATION IN THE VIBURNUM TREND, Rod P. Haenni, University of Missouri-Columbia, 65201. The dolomites in the Bonneterre Formation become increasingly stoichiometric and the Mn/Fe ratio increases with increasing proximity to the sulfide mineralization in the Viburnum Trend. The cathololuminescent examination of 150 polished thin sections made from selected intervals of drill cores traversing the Viburnum Trend reveals compositional zoning in the dolomite crystals, due to fluctuating Ca/Mg and Mn/Fe ratios in the ancient dolomite forming brines. Selected dolomite crystals were analyzed under the electron microprobe to determine exact composition. The examination of Ca/Mg and Mn/Fe ratios as outlined above may prove useful in prospecting for stratiform ore deposits in carbonate rocks.

RAPID FRACTIONATION OF PHOSPHATE IN ANTHROSOLS, William I. Woods, Southern Illinois University at Edwardsville, Edwardsville, 62026. Quantities of nutrient-rich debris are deposited at human settlements. The phosphate component of these materials is rapidly immobilized in the soil creating zones with unnaturally high phosphate levels. Though soil phosphate analysis has long been used as an aid to abandoned settlement studies, several problems have been encountered with the chemical techniques routinely utilized. A recently developed system for the franctionation of soil phosphate is presented which eliminates many of these problems. Preliminary results obtained from the analysis of a variety of natural and culturally influenced soils collected in southwestern Illinois indicate that the technique can be employed for the rapid identification of human deposited phosphate anomalies.

LINQUISTICS

The Etymology of Slavic *plug- 'plow'--D.T. Murphy

Most investigators ascribe the Slavic word for the heavy, two-wheeled plow to Germanic, e.g., OHG Pfluog. The question of whether it is a native Germanic word is still debated. Vasmer, e.g., argues that it is. In 1964, Potter argued convincingly for non-Germanic origins, holding for Celto-Raetian, as originally reported by Pliny. Potter adds that the Slavs did, however, borrow the word from Germanic. The present writer argues for an indigenous Slavic origin for *plug-, based upon the relevant Czech data, though not excluding the possibility of of the influence of a Celto-Raetian cognate based upon the IE root *pleu-/*plou-.

LANGUAGE STABILITY AND CHANGE: A SOCIOLINGUISTIC MICRO-STUDY OF AN OZARKS FAMILY. Carol C. Mock, Southwest Missouri State University, Springfield, 65802. Language change in "apparent time" can be studied by observing the speech of people of different ages; influential social factors behind language change begin to emerge when detailed biographical and socio-economic information is also available. Four generations of a family living in rural Christian County, Mo., are under ethnographic study as part of a multidisciplinary research project at SMSU. Linguistic analysis of selected phonological and grammatical variables in the speech of members of this family has indicated the relevance of peer groups, even within a rural setting, for the direction of language change.

TEMPORAL ANALYSIS OF ENGLISH AND SPANISH NARRATIVES, T. Johnson, and D.C. O'Connell, St. Louis Univ., St. Louis, 63108. Ninety young men, 45 native speakers of English(USA), and 45 native speakers of Spanish(Mexico) were asked to retell a story presented as: 1)film plus narrative; 2)film only; 3)narrative only. Narratives were in subjects' native language. The different demands on cognitive processes were evident in the results of speech rate and pause frequency and length. A certain parallelism was found in the performance of both language groups, while language-specific differences were found in vocal hesitations. Cross-linguistic comparisons support the reliability of paralinguistic measures to study the relationship of thought and language, as some aspects of speech generation are not necessarily evident in the semantic or grammatical structure of produced discourse.

A PRELIMINARY SURVEY OF MODAL ELEMENTS IN MAYAN LANGUAGES, Katherine Martin, Washington University, St. Louis, MO. 63130. Positional tendencies of modal elements across languages have been examined by Susan Steele during 1973 to 1975 and were found to yield sentences with modal elements in initial or second positions. This paper surveys several Mayan languages in order to test these conclusions and to observe to what degree variation may exist within one language group. Basic unmarked word order for sentences in the Mayan sample is compared with the modal patterns observed in these languages. Sentence-initial positions for modal elements are evident in eleven Mayan languages, and second position for ten. Seven languages seem to exhibit both modal positional patterns and include three types of syntactic structures: modal phrases or complexes, modal elements in verbal or nominal phrases and independent modal elements in sentence-initial positions. Several avenues to explore as to possible reasons for the duality in modal patterning are suggested.

WHAT IS "GRAMMAR"? Donald M. Lance (Linguistics, University of Missouri-Columbia, Columbia, MO.). The term "grammar" has three common meanings: (1) a description of the word-forms and sentence components of a language, (2) a "laundry list" of prescribe and proscribed usage items, (3) the conventions of formal written language, and (4) abstract "rules" that a human being has internalized and that enable him/her to produce understandable utterances in a variety of spoken or written styles. Foreign language teachers are most concerned with (1), English and Speech teachers with (2) and (3), and linguists with (4).

ETYMOLOGY OF SKEDADDLE, Gerald Cohen, University of Missouri-Rolla, Rolla, 65401. The origin of skedaddle is currently uncertain, with five hypotheses in existence on the subject and with confusion added by the presence of English dialectal skedaddle (= to spill). I will set forth the research I have done on the subject and defend as correct an etymology which is currently almost universally rejected, viz. skedaddle <Greek skeda- (= to scatter).

MATHEMATICS

ON EVALUATING THE PARTIAL SUMS, Mangho Ahuja, Southeast Missouri State University.

HOW TO TEACH INTRODUCTORY MATHEMATICS, Elizabeth Berman, University of Missouri-Kansas City. How do you motivate students who enter college fearing mathematics? The best motivation is to show the student that you are a kind human being who cares about the student. Another motivation is to present simple, interesting applications. From the application you derive a function; from the function, an equation; and, in order to solve the equation, you teach algebraic techniques.

HOW RATIONAL IS A CIRCLE? R. L. Boehning, Missouri Southern State College. Several theorems from high school geometry level to undergraduate number theory concerning the number of rational points on a circle. Motivation comes from Pasch's axiom, pythagorean triples, and elementary use of the centrapositive.

ODD ABUNDANT NUMBERS, Rik Drummond, Central Missouri State University. The paper defines and discusses odd abundant numbers. One of the theorems states: there does not exist an odd abundant number whose exponent sum, of the prime factorization is four or less. Also discussed is the search for the smallest odd abundant number without three and five as factors.

THE FACE-CENTERED CUBIC LATTICE, Charles Ford, St. Louis University. The purpose of this talk is to illustrate some of the elementary, yet very interesting mathematics that is useful in the study of crystals and solids. We will feature three-dimensional models to illustrate the unique properties of the face-centered cubic lattice. The points of this lattice correspond to the centers of spheres of equal radius arranged in a close-packed structure. This is one of the fourteen basic lattice structures assumed by the crystals and belongs to the crystal system exhibiting the greatest symmetry. We will discuss this symmetry and illustrate some familiar crystals, such as rock salt and zincblende, with a face-centered cubic structure.

MEASURES WITH ORTHOGONAL VALUES, Victor H. Gummersheimer, Southeast Missouri State University.

FIXED POINT ITERATIONS USING INFINITE MATRICES, Troy L. Hicks, University of Missouri - Rolla. I will discuss different iteration processes for finding a fixed point of a given function. Infinite matrices will be used to define these processes. A new important generalization of the Banach fixed point theorem appeared in 1976. Unlike Banach's theorem, no method of locating a fixed point is known. I will discuss what progress has been made on this problem.

SOME EFFECTS OF ADMINISTRATIVE POLICIES CONCERNING GRADES ON STUDENT PERFORMANCE, George C. Ragland, St. Louis Community College at Florissant Valley. The purpose of this research was to determine what effect, if any, changes in administrative policy on grading have on student performance as indicated by the recorded grades. These specific areas of policy change in the St. Louis Community College were studied: 1) Changes in policy on withdrawal from class. 2) Differences in itial student placement in the developmental mathematics course sequence. 3) Changes in the policy on Incomplete grades.

SYSTEMS OF FIRST ORDER HYPERBOLIC EQUATIONS, E. L. Roetman, University of Missouri - Columbia. Systems of hyperbolic equations include the second order wave equation as a special case as well as many other equations. Treatment of simple systems clarifies the classification criteria and the domain of dependence problem. The d'Alembert solution for the elementary second order wave equation is obtained again by two distinct methods, one of which suggests techniques for generalization to higher dimensions.

SYSTEMS DYNAMIC MODELING AND COMPUTER SIMULATION, John T. Sieben, Tarkio College. Part 1 of this paper treats reasons for and methods of modeling, as well as outlining the historical development of modeling techniques. Concluding Part 1 is a look at modern applications of simulation. Part 2 is a report on a class in Systems Dynamic modeling and Simulation taught at Tarkio College with illustrations of students' models and the computer runs that implement the models. The conclusion explores possible futures of modeling techniques and the place of modeling in the liberal Arts curriculum.

AN EXACT ALGORITHM FOR THE SMALL SCALE TRAVELING SALESMAN PROBLEM, Robert C. Shock, Southern Illinois University, Carbondale, 62901. A branch and bound algorithm is presented, and this algorithm differs from others in that the cost matrix is arranged in a row tableau and column tableau. These tableaux are used throughout, and a special mark out process blocks subtours as a tour is built.

A GENERAL SOLUTION OF WHITTAKER'S TYPE FOR THE BIHARMONIC EQUATION IN THREE VARIABLES, Herbert H. Snyder, Southern Illinois University.

METEOROLOGY AND CLIMATOLOGY

FLIGHT DEPLOYMENT AND ON-BOARD METEOROLOGICAL ASPECTS OF SPACE SHUTTLE, Clarence A. Zacher, Project Spaccule, St. Louis, Mo.

THE GENERALIZED DATA BASE MANAGEMENT APPROACH TO CLIMATOLOGIC RESEARCH, Ronald R. MacDonald, Argonne National Energy and Environment Systems Division Laboratory.

APPROACHES TO MODELLING WHEAT YIELD VARIATIONS, Daniel W. Bridge, University of Louisville, Kentucky.

AN ALTERNATIVE INDEX FOR RELATING GRAIN PRODUCTION TO CLIMATIC VARIABILITY AND TRENDS, D. W. Bridge and R. Clark, University of Louisville.

HUMAN CLIMATIC CHANGE AND ITS POTENTIAL IMPACT ON THE IMPENDING GLOBAL FOOD CRISIS, Redmond Clark, Elmhurst College.

MICROBIONICS

FIELD AND LABORATORY STUDIES IN ARBOVIROLOGY, Gary G. Clark, Illinois Department of Public Health, Chicago, 60612. During 1975, there was widespread occurrence of St. Louis Encephalitis (SLE) in Illinois where approximately 600 cases and 47 deaths were reported. As a result, a statewide surveillance program was established to provide warning of early or high levels of SLE virus transmission. Evidence of transmission was first detected in birds collected in mid-June in central and southern Illinois and reported to the public in early-July. The onset of the first human case was in mid-July, but not confirmed until the third week of August. The recognition of virus transmission before human infection occurred points to the value of this program.

DRY MASS CHANGES IN GERMINATING SPORES OF DIPLODIA MAYDIS AND FUSARIUM ROSEUM. A.J. Pappelis, Pauline Mumford, S. Mayama, M. Mayama, and L. Wu. Dept. of Botany, Southern Illinois University, Carbondale, IL 62901. The dry mass of multicellular spores of Diplodia maydis and Fusarium roseum was measured using quantitative interference microscopy. Dry mass of D. maydis spores declined 50% on germination, whereas F. roseum spores remained relatively unchanged. When means for both spore and germ tube were considered, the total dry mass of both often exceeded that of the dry mass mean of the spores prior to germination. In the case of D. maydis, we propose that germ tubes absorb nutrients released by spores that did not germinate.

ULTRASTRUCTURAL CELLULASE LOCALIZATION IN THE FUNGUS, DIPLODIA MAYDIS. Judith A. Murphy, M.R.Thompson, and A.J.Pappelis. CTR. for Electron Microscopy, Dept. of Botany, So. Ill. Univ., Carbondale, IL 62901. Cellulase activity produces glucose as an end product which can be made to reduce cupric salts to cuprous oxide precipitate in an alkaline medium. Cuprous oxide can be visualized with an electron microscope because it is electron dense and the Cu component can be verified with the use of an x-ray analyzer. In samples prepared for SEM and TEM, copper deposits indicating the reaction product were found on hyphal surfaces. In samples without a specific inducer, a small amount of reaction product was found inside the cells indicating the constitutive nature of the enzyme. The ultrastructural results agree and support the inferences made from biochemical studies concerning the location of the active enzyme on the hyphal surface.

COMPARISON OF THREE COMMONLY USED METHODS FOR EXTRACTING DNA FROM BACTERIA, Susan K. Amundsen and M. E. Neville, Illinois State University, Normal, 61761 DNA was isolated from Escherichia coli, Bacillus subtilis, and Arthrobacter globiformis by methods employing chloroform-isoamyl alcohol, phenol, or enzymes. The effects of concentration of cells, amounts of reagents, and temperature of dialysis on yield and fragmentation of DNA and removal of RNA and protein by each method were studied. The chloroformisoamyl alcohol and phenol procedures give comparable yields and purity. On the other hand, the enzymatic method gives higher yields, but protein contamination is very high. These results emphasize that the type of bacteria and the desired characteristics of DNA for experimental purposes must be considered in selecting an extraction procedure.

ECOLOGICAL STUDIES ON CORYNEFORM BACTERIA FROM SOILS OF CENTRAL ILLINOIS, Kathleen W. Miller, Illinois State University, Normal, Illinois 61761. The distribution of coryneform bacteria in soil was investigated. Soil samples from a cornfield, river bottomland, grassland and hardwood forest in McLean County, Illinois, yielded 253 coryneforms. The isolates were characterized using 42 morphological and biochemical tests. Characteristics which varied significantly with the sampling area included pigmentation, colony morphology, litmus reduction, and utilization of sugars, aromatic hydrocarbons, and citrate.

PURIFICATION OF THE ENTEROBACTERIAL COMMON ANTIGEN BY AFFINITY CHROMATOGRAPHS, John W. Measel, Jr., Kirksville College of Osteopathic Medicine, Kirksville, Mo. 63501. Antibodies made to the Enterobacterial Common Antigen (ECA) of E. coli 014 were fractionated and chemically hooked to inert beads. ECA made from E. coli 0111 was then reacted with the conjugated antisera and washed. The ECA was released from the bound antibody by acid-salt treatment and analyzed by amino acid analysis and hemagglutination. This material was reactive serologically, but could not induce antibody formation in rabbits. Isoelectric focusing showed that the pI of the material to be approximately 5.0 on both the crude and the purified material. This data combined with previous work indicates that the ECA consists of a loosely bound combination of two or more molecules of amino acids, sugar and lipid. One of these molecules is the ECA which is haptenic in nature and cannot induce antibody formation unless it is in the crude (associated) state.

POLYMER FORMATION FROM METHANOL BY ACTIVATED SLUDGE FROM SEVERAL SOURCES, Edwin N. Davis, Northern Regional Research Center, ARS, USDA, Peoria, Ill. 61604. (Ref.:Appl. & Environ. Microbiol., 32 (2), 303-305, 1976) Four municipal waste disposal plants supplied activated sludge containing organisms which produced a viscous product from methanol. Activated sludge from a corn products plant made polymer only if acid was repeatedly neutralized. Ten-liter fermentations with variables of aeration, backseed, and timing of methanol additions were sampled for seven days for viscosity and residual methanol. After all methanol was consumed, polymer was hydrolysed with reduction in viscosity. Readily soluble freeze-dried crude product was made. The viscous product mixed with pesticides has been found to be a promising slow-release agent.

A STUDY OF THE EFFECTS OF AMINO ACIDS ON SPORULATION IN BACILLUS SUBTILIS. Pattle Pun, Richard Szucs and Thomas Franke, Dept. of Biology, Wheaton College, Wheaton, IL. 60187. The patterns of transcription has been found to be closely associated with the onset of sporulation in B. Subtilis. A mutant which contains all the information to make its own amino acids during vegetative growth, but because of a single mutational event in the RNA polymerase gene, requires several amino acids for normal sporulation was isolated. Four highly phosphorylated nucleotides (HPN) found in sporulating cells are implicated in regulating the initiation of sporulation. Preliminary experiments were done to compare the production of HPN in the mutant induced to sporulate in the presence and absence of the amino acid supplements.

CYTOPHOTOMETRIC MEASUREMENT OF RELATIVE FEULGEN NUCLEAR DNA CONTENT AS INDICATION OF DIVIDING AND NONDIVIDING NORMAL HUMAN SKIN FIBROBLASTS IN CULTURE, Song-chiau Lee, A. J. Pappelis, P. M. BeMiller and J. N. BeMiller, Southern Illinois University - Carbondale, 62901. Normal human skin diploid fibroblasts from donors of three different ages (El San, 8 years; Ar Mor, 40 years; Al Pos, 84 years) were studied using cytophotometry in conjunction with histochemical procedures. Single poles of telophase mitotic figures were used to determine 2C F-DNA values, and metaphase mitotic figures were used to determine the 4C F-DNA values. A large number of cells in S phase were found in early passage culture, while the last passage culture showed a marked reduction in the number of cells in S phase and an increase in 2C F-DNA values. The data indicates that the number of noncycling cells increase as cells age in culture.

NUCLEAR AREA CHANGES DURING LOG AND PLATEAU PHASE OF GROWTH IN NORMAL HUMAN SKIN FIBROBLASTS AND MOUSE EMBRYONIC FIBROBLASTS IN CULTURE, Son-chiau Lee, A. J. Pappelis, B. M. BeMiller, and J. N. BeMiller, Southern Illinois University - Carbondale, 62901. The nuclear area (NA) was determined in this study using an interference microscope with a Leitz Orthomat Camera. The fibroblast cultures were maintained as monolayered at 37C in 60mm Falcon plastic petri dishes in an atmosphere at 5% CO_2-95% air by feeding them with Dulbecco's Modified Eagles Medium supple-supplemented with 10% fetal calf serum every other day. The NA in ELSan (8 yrs, p. 20), ArMor (40 yrs, p 6), AlPos (84 yrs, p 14) was 15.4, 19.2, and 19.7 x 10^{-7} cm^2 during log phase of growth and 11.9, 14.4 and 17.1 x 10^{-7} cm^2 during plateau phase of growth respectively. NA did not change in a mouse embryo fibroblast aneuploid cell line that did not exhibit contact inhibition.

ULTRASTRUCTURAL STUDIES OF THE EFFECTS OF NICOTINE ON THE CARDIAC TISSUES OF THE RAT. James Smith, David Martinez, Glenn Sedjo, Edward Simonsen and Pattle Pun, Dept. of Biology, Wheaton College, Wheaton, IL. 60187. Nicotine which was known to cause the constriction of coronary arteries was fed to Sprague Dawley strain of rat, Rattus norvegicus in drinking water at different concentrations. The rats were sacrificed after eighteen days and the cardiac tissues were fixed in glutaraldehyde and osmium tetroxide, dehydrated with alcohol and propylene oxide and embedded in epon. Sections were examined with an RCA-EMU-3F electron microscope. Electron Micrographs of control rats and treated rats were compared. Other pertinent tissues were also examined.

EFFECTS OF pH ON THE BIOCHEMICAL ACTIVITIES OF SELECTED ALKALOPHILIC BACTERIA, Lawrence N. Schmidt and Betty J. Cole, Illinois State University, Normal, 61761. Six strains of alkalophilic bacteria isolated from alkaline environments have been tentatively identified as species of Staphylococcus, Streptococcus and Enterobacteriaceae. The effect of pH on cultural and biochemical characteristics was studied by performing tests at pH 7.0, 8.5 and 10.5. Distinct differences in colonial morphology were observed. More intense pigmentation and more rapid cellular growth rates were found at alkaline pH's. Many biochemical tests gave positive results more rapidly after the initiation of growth in alkaline media than in neutral media. Certain enzyme activities, including amylase, gelatinase, cytochrome oxidase and lipase, were detected only at alkaline pH's.

PHYSICS

MAGNETIC MODEL OF THE COVALENT BOND, T. B. Holiday, Elmhurst College.

THE CASE FOR IC'S IN UNDERGRADUATE ELECTRONICS, Raymond G. Wilson, Illinois Wesleyan University.

EVALUATION OF A TOTAL COMMITMENT COURSE IN PHYSICS FOR MAJORS, Richard Valentine and David A. Cornell, Principia College.

A NOT-SO-SIMPLE DIFFERENTIAL EQUATION, Gary Kessle, Illinois Wesleyan University.

OPTICAL IMAGE TREATMENT BY SPATIAL FILTERING, A. Scott Moreau and Howard Klaasen, Wheaton College

CHARACTERISTICS OF THE SOLUTIONS OF THE RATE EQUATIONS FOR RF DISCHARGE IN ARTON Steven G. Sanders, Southern Illinois University - Edwardsville.

ENERGY SCALE CORRECTION METHODS FOR MODEL SOLAR HOMES. Thomas M. Holzberlein Principia College

CONTEMPORARY PHYSICS AND ITS IMPACT ON SOCIETY, A COURSE, Edwin J. Schillinger DePaul University.

CORIOLIS DEFLECTION IN A RAPIDLY ROTATING ALIEN SPACECRAFT, Richard P. Cebula, Walter J. Cygan and Andrew F. Rex, Illinois Wesleyan University.

ON THE TECHNIQUES OF GREEN'S FUNCTIONS PROBLEMS IN PHYSICS, P. N. Swamy Southern Illinois University - Edwardsville.

DETERMINATION AND MEASUREMENT OF SCIENTIFIC THINKING: IMPLICATIONS FOR TEACHING PHYSICS--Ernestine M.J. Long, University of Missouri-St. Louis. College teachers have been anxious to bridge the gap between high school and college instruction in physics. More quantitative thinking has been introduced to make the curriculum more rigorous at both the secondary and higher educational level. This has had the effect of limiting enrollment in physics to students proficient in mathematics. The Downing Long test of scientific thinking was administered to 1640 students in two universities, two colleges, one junior college, and four high schools. Results indicate students gain more in ability to think scientifically during the eleventh and twelfth grades than at any time in their lives. Boys reach a peak in cognitive growth in their junior year of college; girls reach their top scores and excell boys in their senior year. A summer 1976 program at UMSL to prevent high ability students from dropping out will be described.

RESEARCH AND APPLICATIONS AT THE UNIVERSITY OF MISSOURI RESEARCH REACTOR, Robert M. Brugger, University of Missouri, Research Park, Columbia, 65201 The University of Missouri has the highest power, highest flux source of neutron plus gamma radiation at a U. S. University. This radiation is used for research by faculty of the University of Missouri, other universities, federal and state agencies and industry. Nine areas of research and application to use this radiation have been identified and are being implemented. These areas are; Radioisotopes Applications, Neutron Activation Analysis, Nuclear Science, Neutron Diffraction Applications, Inelastic Scattering Applications, Neutron Properties, Neutron Radiography, Radiation Applications, Nuclear Engineering Applications. Examples of recent research in these areas will be presented.

EXCESS PROPERTY: BOON OR BOONDOGGLE? Donald D. Miller, Central Missouri State University, Warrensburg, MO. The General Services Administration's Excess Property Program presents a means whereby educational institutions can acquire apparatus and components otherwise beyond their already strained budgets. However, there are some drawbacks inherent in this "sugar". My experiences with this program, including gains and losses, will be presented.

SOME ADVICE FOR AUTHORS (AND PUBLISHERS), S.J. Morris, Three Rivers C.C., Poplar Bluff, MO. "Some books are to be tasted, others to be swallowed and some few to be chewed and digested." (Bacon) Henceforth teachers should demand from authors and publishers alike certain fundamental requirements before agreeing to purchase textbooks for physics classes. Of particular importance are insistence on the use of MKS units throughout, better than run-of-the-mill treatment of topics and an emphasis on applications. Color slides, prepared transparencies and apparatus will be shown to illustrate how chapters could be improved.

MICROWAVE OPTICS, ELECTROMAGNETIC FIELDS, AND LABORATORY HAZARDS, M. Drake Bell, Physics Department, Central Missouri State University. Electromagnetic waves with λ between 300 m and 3 mm may be absorbed in biological tissues. Wavelengths of 12.2 and 3 cm are of special interest because of widespread use in physics laboratories. In addition, microwave ovens operate at 12.2 cm. The Cenco microwave transmitter (No. 80422-00) used in microwave optics experiments emits 12.2 cm waves and has a rated power output of 300 milliwatts. The power density measured near the antenna is 2.6 mW/cm^2 at maximum output. This corresponds to 98 V/m and 0.26 A/m for the electric and magnetic fields respectively. In view of the present USA safety standard of 10 mW/cm^2 for 24 hours, there appears to be no safety hazard. However, if one accepts the USSR levels of 0.01 mW/cm^2 for 8 hours, the microwave system should receive careful evaluation with regard to its educational use.

FAR INFRARED PROPAGATION DISTANCES OF SURFACE ELECTROMAGNETIC WAVES ON Ni, Pd, Pt, AND W METAL SURFACES, D. L. Begley, R. Miller, R. W. Alexander, and R. J. Bell, University of Missouri-Rolla, Rolla, Mo. 65401. The far infrared propagation distances of surface electromagnetic waves on Ni, Pd, Pt, and W metal surfaces were measured using the two-prism coupling technique. A molecular waveguide laser was optically pumped by a CO_2 c.w. laser providing coherent rediation between 40 and 200 um. Experimental and theoretical results agree well.

CHARACTERISTICS OF A TUNABLE DYE LASER PUMPED BY A XENON ION LASER.--L.D. Schearer (University of Missouri-Rolla, Rolla, MO 65401) A xenon ion laser ($\sim$3kw, 300 nsec) used to pump a sealed dye cell containing Rh6G in an astigmatically compensated 3-mirror cavity containing a birefrigent filter yields the following dye laser characteristics: 30-40% conversion efficiency in 0.15nm bandwidth; 250 nsec pulse width @ $\sim$1.4 kw/pulse; 2% conversion into UV by SHG with KDP. Repetition rates to 30 Hz with inexpensive components is readily obtained. A tuning range from 540 nm through 700 nm has been obtained with different dyes. Extension to the blue dyes can be accomplished by utilizing the large peak powers available at 3645Å from the xenon ion laser.

DISSOCIATIVE CHARGE TRANSFER CROSS SECTIONS FOR NEGATIVE IONS, George F. Hagner, University of Missouri-Rolla, Rolla, MO 65401. Measurements of dissociative charge transfer between atomic negative ions and H_2 will be presented. The reactions are of the form $X^- + H_2 \rightarrow H + H^- + X$.

The primary ion had an energy range of 50 eV to 10 keV. A crossed beam technique was used with product ion extraction normal to the plane of the intersecting beams. The measured relative cross sections were normalized to the measurements of $H_p^- + H_2 \rightarrow H^- + H_p + H$ by Snow, et. al.[1]

[1]W.R. Snow, R.D. Rundel, R. Geballe, Phys. Rev., 178, 228 (1969).

A DIGITAL CONTROL PROGRAM FOR AN EXPANSION CLOUD CHAMBER, Kevin Menke and Donald Hagen, University of Missouri-Rolla, Rolla, Mo. 65401. The Graduate Center for Cloud Physics Research has an experimental cloud simulation chamber which is designed for the study of cloud microphysics. This chamber is connected to a Nova 840 minicomputer which handles the data acquisition and control for the chamber. The purpose of this paper is to describe the real time data acquisition and control program used during a current series of experiments. The program is in Fortran and uses a multi-tasking approach to handle the various jobs which must be performed during the experiment.

WILHELM CONRAD ROENTGEN AND HIS DISCOVERY OF X-RAY--Newell S. Gingrich University of Missouri, Columbia. Roentgen directed his efforts toward becoming a mechanical engineer but was attracted by Kundt to become a physicist. By 1895 at the age of 50 he had published 48 papers on a variety of subjects when he turned his attention to experimenting with discharge tubes and discovered what he called X-rays. He published three papers describing the properties of X-rays and then turned his attention to other studies. A brief review will be given of his life and his work.

SCIENCE EDUCATION

OPEN-MINDEDNESS AND RIGIDITY TO CHANGE IN SECONDARY EDUCATION SCIENCE MAJORS, Loren Denney, Southwest Missouri State University, 65802. Psychological open-mindedness and willingness to change were measured as attributes of science teachers. The Rokeach Scale was administered to students in Science Teaching Methods classes. Results indicate these students are open-minded, but not willing to change their beliefs or ideas. Conclusion is that methods and techniques of training need to be altered to decrease rigidity to change.

THE CONTINUOUS PROGRESS SCIENCE CURRICULUM IS ALIVE AND WELL AT PARKWAY NORTH SENIOR HIGH SCHOOL, G. Wayne Mosher, Parkway North Senior High School, Creve Coeur, MO 63141. A Continuous Progress Science Program which uses behavioral objective based learning packets as the curriculum tool has been implemented over the last three years at Parkway North Senior High School. Approximately 850 science students are affected. Results indicate that approximately 16% of all science students were able to complete courses prior to the end of the 1975-76 school year and begin new courses or work ahead of the majority of the class. Results of standardized test scores will be presented along with methods of classroom management which facilitates small group work and effective evaluation.

A SURVEY OF SCIENCE EDUCATION IN ILLINOIS SCHOOLS, GRADES K-6, 1975-76, Thomas C. Fitch and Robert Fisher, Illinois State University, Normal, 61761. Extensive survey research results of elementary school science curricular programs in use in Illinois schools, with obstacles to science teaching identified, sources of assistance for improving science education named, and science teaching practices found in Illinois schools described. Results cover all aspects of science education. Data will be available to participants in the form of handouts.

PROGRAMS, PRACTICES, AND PROBLEMS IN SCIENCE EDUCATION: A SURVEY OF ILLINOIS SCHOOLS, Robert L. Fisher and Thomas Fitch, Illinois State University, 61761. In May of 1976, a survey was conducted to determine the status of science education programs in pre-college classrooms in Illinois. The results of the study to be presented in this section describe the information includes courses taught, programs used, number of teachers and pupils involved, and enrollment trend. It also includes the respondents opinion of the problems and practices of science education in that school.

VISUAL PERCEPTUAL ABILITY AND BIOLOGY ACHIEVEMENT, Melba L. James, Parkway West Senior High School, Ballwin, MO 63011. "A picture is worth a thousand words" is a common cliche in educational circles. Numerous studies have not supported this. These studies have quite variable data and inconsistent patterns. Piaget's studies on perceptual activities suggest a temporal development of "perceptual abilities" and suggests a link of them to the development of conceptual abilities. A study to measure students "perceptual activities" and to correlate these to their perceptual usage in biology, biology achievement, intellectual ability, age, and sex was conducted. In this report, Piaget's perceptual activities were discussed. David Elkind's tests which were used in the study to measure perceptual activities were shown. The means used to measure student's perceptual use in biology, biology achievement, and intellectual ability were presented. The study's findings, if available were reported.

DEMONSTRATION OF COMPETENCE IN INTRODUCTORY EXERCISES OF SCIENCE - A PROCESS APPROACH BY PRE-SCHOOL CHILDREN, E. W. Krebs, A. J. Pappelis, and T. K. Kraft, Southern Illinois University, 62901

A COMPARISON OF ALTERNATIVE APPROACHES AND MATERIALS FOR TEACHING A UNIT ON POPULATIONS, Adell Thompson, University of Missouri-Kansas City, 64110. The problem in this study was to determine which of four combinations of alternative instructional approaches and sets of curricular materials dealing with the concept "populations" would be most effective for teaching students certain principles and processes of environmental education as they relate to this concept. Results show that when approaches were pooled together there were no significant differences, but there was a significance between an interaction of approaches and materials. Finally, from the statistical analysis of the data and the results of the textable hypotheses, these conclusions were drawn: other things being equal, 1) it was determined that the integrated approach appears to be better suited for use with the specially-prepared materials; 2) the non-integrated approach appears to be better suited for use with commercial materials.

IMPROVING PROCESS SKILLS AMONG PREMEDICAL AND PREDENTAL STUDENTS USING SCIENCE - A PROCESS APPROACH MATERIALS, Christine K. Pappelis, A. J. Pappelis, and Mary M. Pohlmann, Southern Illinois University, Carbondale, 62901. Students were pretested with the Test of Science Processes developed by Robert S. Tannenbaum over a 6 semester period. The class met for a 2-3 hour block per week and emphasized materials and activities drawn directly from the Science - A Process Approach curriculum or modified for use with university biology majors. Psychological and communicating exercises were modified to stress medical literature and clinical methods. The mean pretest score was 74 (N=38) out of a possible 96, not much better than the mean of 62 for the junior high school norm used by Tannenbaum and the mean of 69 for S.I.U. non-science majors. All semesters there was a pre- to post-test increase.

AN INTERPRETATION OF STUDENT ACHIEVEMENT TEST RESULTS: ISCS vs. TRADITIONAL LIFE, EARTH, PHYSICAL, Verlin M. Abbott, Parkway School District, Chesterfield, MO 63017. Parkway is a suburban St. Louis School District having twenty elementary, six junior high, and four senior high schools. All elementary schools use ESS. Each junior high science staff has been permitted to choose the curriculum used in their building. Two have selected ISCS. Four teach a Life, Earth, Physical sequence. This study was an attempt to analyze SRA achievement test scores of first month tenth grade students coming from the various junior high programs into the senior high.

FUN YET INSTRUCTIVE EXPERIMENTS IN PHYSICS, Dr. George Bedard, Parkway North Senior High School, Creve Coeur, MO 63141. A series of interesting physics demonstrations dealing with motion, light, and nuclear physics will be shown. Emphasis will be on ease of set-up, low cost, interest to the student, and application to the high school physics course. Equipment permitting, demonstrations will be shown to the group. Application to other science disciplines will be pointed out.

GEOBOARDS AND QUADRILATERALS IN HIGH SCHOOL GEOMETRY, Lotus D. Hershberger, Illinois State University, Normal, 61761. The study of quadrilaterals was done by use of the geoboard. When the study of quadrilaterals was to begin, the regular text book was collected, the students were divided into small groups, and the geoboards were used as the vehicle for investigation of quadrilaterals and their properties. Some guidance was provided but guessing was encouraged, conjectures were formed and verification of conjecture was required. Summaries of the small group work for the total class were compiled.

USING NAFAX METEOROLOGICAL MAPS TO TEACH BEGINNING WEATHER, Edward M. Fashing, Triton College, River Grove, Illinois 60171.
A discussion of classroom use of NAFAX mereorological maps to teach beginning weather in a Physical Science course. Additionally a multiple 7 point XY recorder is being used to graph local parameters simultaneously and to demonstrate various relationships in the troposphere which are of value in the classroom. Present and future weather conditions can as a result be intelligently discussed from a now point of view obtaining better learning and student interest.

SI AND HOW TO TEACH IT, Wilson P. Banks, Illinois State University, Normal, 61761.

INVESTIGATION OF THE USE OF REMOTE SENSOR IMAGERY FOR LAND RESOURCE MAPPING, C. Dale Elifrits, University of Missouri-Rolla, 65401. Information contained in this report is a result of investigation and analysis of several land resource mapping methodologies for interpreting remote sensor imagery. Land resource classifications were made at Levels I, II, and III. Procedures varied according to type of imagery/photography and equipment used. A comparison of methods investigated in this study and other methods used by government agencies was made. Time factors were calculated on the basis of operator manhours. Benefit criteria for the different methodologies included simplicity and number of steps required for a finished map, ease of mapping and operator fatique, accuracy, and degree of detail achieved at each level of mapping.

RELATIONSHIPS BETWEEN COGNITIVE AND CONTENT STRUCTURE OF PHYSICS CONCEPTS, Sr. Patricia Thro, Maryville College, 63141. This research effort investigates (a) the development of physics concepts in cognitive structure considered as a result of the content structure presented to the learner and (b) the relation between cognitive structure and problem solving ability. Thirty subjects, who were divided into a treatment group (N=19) and a control group (N=11), participated in this research. An analysis of variance confirmed that experimental subjects' cognitive structures indicated significantly greater coorelation with the model of content structure after exposure to it than previously ($p < .001$). Comparison of regression models showed that cognitive structure itself contributes significantly to the prediction of achievement ($p < .001$). Cognitive structure allows greater insight into a learner's progress than achievement testing does.

AN EARLY FIELD EXPERIENCE FOR PROSPECTIVE SECONDARY SCHOOL MATHEMATICS TEACHERS, Lynn H. Brown and Conrad E. Carroll, Illinois State Univ., Normal, 61761. The authors involve preservice interns from a secondary mathematics methods class in a high school mathematics class. This is one aspect of the ISUM Model. The preservice teachers develop skills in observation and in teaching are the main areas of emphasis in this early field experience. A strategy may be defined as a temporal sequence of moves in teaching concepts, generalizations, and skills. Moves are teacher actions related to mathematics content.

IONIZATION ENERGY DATA IS THE KEY TO STUDENTS UNDERSTANDING OF THE ENERGY LEVEL STRUCTURE OF MANY ELECTRON ATOMS, Calvin F. DeLano, Parkway West Senior High School, Ballwin, 63011. Careful examination of ionization energy data of the elements reveals not only the principal energy levels but also the sub-energy levels of the electrons in many electron atoms. Students discover the existence of energy levels through graphing and they gain understanding of their discoveries via self-study, teacher demonstration, in class group investigations and group discussion. A key phase of the teaching strategy involves the use of a floating magnetic needle model in an in-class teacher-student manipulated investigation. After handling this data and this model at the concrete level, students are much more receptive of the abstract Quantum-Mechanical Theory of the atom as developed in most chemistry courses.

STRATEGIES FOR TEACHING MATHEMATICS, Kenneth A. Retzer, Illinois State University, Normal, 61761. An overview of current work in strategies for teaching mathematics, including their research basis, current coordination of research through the Georgia Center for the Study of the Learning and Teaching of Mathematics and its use in teacher education programs for secondary mathematics teachers -- such as the ISUM model program at Illinois State. Acting on the assumptions that teaching is a sociological operation that is observable and that what a teacher does is affected by the type of subject matter taught, taxonomies of

teacher actions, called "moves", have been developed and used in preparing, executing and evaluating lessons; in diagnosis and remediation; in teacher evaluation based on competency criteria; and in descriptive and comparative research. Implications for extension of this work to the teaching of science will be explored.

FROM FACT TO IMPACT, John R. Carlock, Illinois State University, Normal, 61761. In past years, science courses were devoted almost entirely to factual aspects. In recent years an increasing emphasis has been given to science as a process; as a form of inquiry; as an investigative matter. Today, concerns are widening that students should be given some view of science as an area which impacts upon the social system and which, in turn, is shaped by the culture. A pilot secondary school course in Science and Human Values is described. Selection of content, materials, and approaches will be discussed.

ENVIRONMENTAL EDUCATION TRAINING PROJECT, Peggy Rustige, St. Louis Public Schools, and Calla Smorodin, Missouri Botanical Gardens, 63110. The Environmental Educaton Training Project is a cooperative program between the St. Louis Schools and the Missouri Botanical Garden. The goal of the project is to develop a model for training teachers of grades 4, 5, and 6 in a multi-disciplinary, multi-process approach to environmental education. The project capitalizes on the fact that a large number of institutions and agencies serve the urban community, providing a wealth of diverse resources in the training of classroom teachers to become environmental educators. An important feature of the project is the organization of a consortium of individuals interested in environmental education. Also the Environmental Education Training Project recognizes that an important role for teachers is to become trainers of other teachers. During the 1977-78 school year, project teachers will help to develop and implement an inservice personnel development program for city teachers.

TEACHING A SCIENCE HONORS SEMINAR COURSE TO FRESHMAN STUDENTS, Norman H. Jensen, Milliken University, Decatur, 62522. Freshmen students who have been selected into the James Milliken Scholars Program are required to participate in a Science Honors Seminar which fulfils their science requirement. The course has been designed around the Ascent of Man series which acts as a guide in the course and to stimulate discussion. Students are assigned to lead the discussion of one of the particular films. Some have had trouble adjusting to it at first. Evaluation of the course has been essentially favorable with most students expressing the feeling that this was a science course different from anything they had previously experienced but indicating satisfaction of what was learned by the end.

TITLE IV ENVIRONMENTAL EDUCATION PROGRAM, John Willenberg, Columbia Public Schools, 65201. The program involves the 4th, 5th, 6th, and 7th grade student and teacher both in the classroom and outdoors with the natural environment through a series of planned learning experiences using out mobile lab as a resource base. Interdisciplinary materials were developed using the Infusion process, ECOS, New York; Task building sequence, U.S. Forest Service; Acclimatization techniques, Steve Van Matre. Teachers receive inservice training prior to an experience. Our test results using T test and Chi square information show a significant improvement in achievement and attitude at the 5% level. The program has been an excellent catalyst for both the community and the school system with many positive spin-offs having already occurred.

THE TEACHING OF EMBRYOLOGY AT THE UNDERGRADUATE LEVEL, Neil M. Baird, Milliken University, Decatur, 62522. This report is based on the results from questionnaires received from more than 100 embryology instructors at midwestern institutions. The study shows that enrollments are stable and/or rising at most institutions. The heaviest emphasis in course content is on general vertebrate development with human development given moderate emphasis at most institutions. Other portions of the study deal with the textbook, the lab manual, lab procedures, and a discussion of various problems and solutions including the problem of trying to cover both descriptive and experimental aspects within a limited time frame.

DEVELOPMENT OF A RELEVANT BIOLOGICAL DICTIONARY, Mr. Vaughan Morrill III, Sumner High School, 63113. This project involves the production of a 3000 term scientific dictionary for students beginning biology at the college level. A file of candidate terms from current instructional materials in the life sciences was constructed. The selected terms were then divided into ten subject areas: history and methodology, biochemistry, anatomy, physiology, genetics, behavior, reproduction and development, evolution, ecology, and systematics. Computer lists for evaluation of terms in these areas were distributed to 30 teaching biologists in local high schools and universities for their assessment of specific term relevance and educational level. Additional terms were also solicited. This data will be subjected to analyses and selected term compilation. All data, including associated definitions, will be loaded into disc storage for editing, updating, and printing out in dictionary form.

ESTABLISHING AND MAINTAINING OF THE MARINE AQUARIUM IN THE CLASSROOM, Michael Surma, University High School, Normal, 61761. The marine aquarium can be a very rewarding and stimulating experience for the student as well as the teacher. You can teach many subject areas from just one aquarium because you have established a completely closed eco-system right in your classroom. The problem most people encounter is the proper technique for setting up the system so that your specimens will be able to live in the world you are providing for them. A few simple steps of establishment and maintenance will pay off in a very exciting learning experience.

A BIOLOGY CURRICULUM FOR EVERY STUDENT, Lona Lewis, Parkway North Senior High School, Creve Coeur, MO 63141. Parkway North Senior High School has developed a Biology Curriculum that appeals to a broad segment of students. There are three courses offered, Exploratory Biology, General Biology, and Advanced Biology. Exploratory is a survey course for low ability and low interest students. Topics and activities were picked that appeal to this category of students, but also offered a good survey of Biology. Of special interest to the staff has been the number of Exploratory students who enrolled the next year in General Biology. General Biology offers the typical units and allows students to move at their own rate. As a result 8% in 1975-76 moved into other courses before the end of the year. Advanced Biology units are those that were not covered in General Biology and provides more indepth work.

PROVIDING DIVERSITY THROUGH INDIVIDUALIZED CURRICULA, George S. Garoian, Southern Illinois University, Carbondale, 62901. The 23 faculty members of the Department of Zoology have arranged individualized curricula for undergraduate majors for eight years. The program has been very successful from both faculty and student perspective and is easy to administer. Major advantages are student involvement and influence in developing their own program and personal acquaintance with faculty in their professional interest.

ZOOLOGY

PHILOPHTHALMUS GRALLI: IDENTIFICATION AND GROWTH CHARACTERISTICS OF AN ORIENTAL EYEFLUKE OF BIRDS INTRODUCED INTO THE UNITED STATES, Paul M. Nollen, Western Illinois University, Macomb, 61455. Since the 1930's, species of oriental snails capable of serving as intermediate hosts for human parasitic flukes have appeared in established populations in southern U.S. In 1964 Tarebia granifera was found in a stream near the zoo in San Antonio, Texas and in 1969 an eyefluke of birds, Philophthalmus sp., was identified from larval stages in this snail population. From snail host, adult size and location, length of redial gut, length of cercarial tail, and type of vitellaria this species is identifed as P. gralli. In growth characteristics it resembles the American marine species, P. hegeneri, more than the freshwater species, P. megalurus. Since this species has previously been reported only from the orient and Hawaii, it is assumed the eyefluke was introduced by infected oriental fowl acquired by the San Antonio Zoo.

HOST-PARASITE RELATIONSHIPS OF ACANTHOCEPHALUS DIRUS, Joseph W. Camp, Illinois State University, Normal, 61761. The population dynamics of Acanthocephalus dirus were studied. A. dirus was recovered from creek chubs, Semotilus atromaculatus, and isopods, Asellus intermedius. The prevalence of infection (percent infection) fluctuated seasonally for both creek chubs and isopods. Female creek chubs had an increased prevalence of infection with increased length. The larval and adult worms were overdispersed within their respective hosts. Larval worms apparently caused a color change, from the normal dark color to a whitish color, in some infected isopods. Environmental and host factors interacted to influence the population dynamics of A. dirus. The whitish colored isopods probably resulted from parasitic interference with the pigment producing mechanisms of the isopods.

CANINE DIROFILARIASIS IN ILLINOIS, Benedict Jaskoski and Bolaji Akande, Loyola University of Chicago, Chicago, 60626. Investigation of the prevalence of Dirofilaria immitis and Dipetalonema reconditum and of mosquito vectors reveals widespread distribution. Examination of blood samples from 55 pound dogs by the Knott technique revealed over 7 percent infection with D. immitis; none of the group had D. reconditum. Examination of 173 blood samples sent by 159 veterinarians from 56 counties in Illinois showed that 166 of the samples had D. immitis while 7 had D. reconditum. Double infections were found in 6 of the above. Anopheles punctipennis, Culex pipiens, and Culiseta inornata were collected and allowed to feed on an infected dog. Mouthparts, thorax, and malpighian tubules were examined for stages of the dog heartworm. Microfilariae from the dog developed to the infective stage only in Culex pipiens.

BEHAVIOR OF AVIAN PREDATORS FEEDING ON BOMBUS AND ITS MIMIC, MALLOTA, David L. Evans, University of Illinois, Urbana, IL 61801. Wild-caught adult Blue Jays and Catbirds are equally likely to eat either Bombus americanorum or a mimic, Mallota bautia, if one or the other is offered simultaneously with a Tenebrio larva or pupa. In contrast, when a bumblebee worker and a mimic were offered together without a mealworm, the birds neither ate nor damaged either insect during the test period.

BOLORIA BELLONA: A NEW RECORD FOR SOUTHERN ILLINOIS, Bruce E. Davis, Pattonville Senior High School, Hazelwood, Missouri 63042. Boloria bellona (Lepidoptera: Nymphalidae) is reported from the Southern Illinois University at Edwardsville campus, Madison County, Illinois. Sightings were made in July of 1975 and 1976. All specimens were observed in the same wet meadow area. The local host plant was not established and none of the immature stages were discovered. Illinois records are known mainly from the northeastern part of the state. The butterfly has not been reported from Missouri.

RESPONSES OF THE ROTIFER ASPLANCHNA BRIGHTWELLI TO WEAK MAGNETIC FIELDS, Edward E. Palincsar and Priscilla K. Dale, Loyola U. of Chicago, 60626. ASPLANCHNA orientation in a natural and weak magnetic field was observed. A field of approximately 18 gauss was compared to the earths field. A controlled clone culture and various age groups were studied. The 18 gauss field altered the orientation of the rotifers. There was a monthly variance pattern where the north pole of the magnet was facing south. Various age levels showed an age correlated response to the magnetic fields. The youngest age group tended to turn further left than the mean path of the control group. Two and three day old animals ("middle-aged" group) tended to stay within 20° of the mean orientation path of the control. Further data analysis will be presented.

GROOMING BEHAVIOR AND FUNCTIONAL MORPHOLOGY OF THE FRESHWATER PRAWN, Palaemonetes kadiakensis. Bruce Felgenhauer, and Frederick Schram, Eastern Illinois University, Charleston 61920.

Grooming behavior and morphology of the pereiopods of the prawn Palaemonetes kadiakensis is described. Since prawns have come to inhabit environments with concentrated amounts of settling organisms and debris, they have developed elaborate systems for its removal. SEM photomicrographs revealed distinct setal types located on the grooming appendages. Each setal type has a distinct morphology and function. The biological implications are examined which reinforce the need for grooming in these animals, and the phylogenetic importance of caridean grooming is suggested.

SPATIAL DISTRIBUTION AND BEHAVIOR OF ORB-WEAVING SPIDERS, D. A. Kangas, W. E. Mowczko, C. L. Galey and M. F. Haskins, Northeast Missouri State University, 63501. Two communities, an old field and a small stream bed, were surveyed for orb-weaving spiders. Five species of orb weavers were found in the old field. Approximately 3.26 spiders were observed per m^2. The three most abundant spiders appeared to be randomly distributed. Three species of orb weavers were observed on the stream beds. In contradiction to literature reports, the stream bed spiders were not randomly distributed but were clumped. Clumping was not clearly associated with abutment sites. Further, spiders in both communities were not randomly distributed vertically. Neoscona praetensis spun higher webs in the field and Neoscona benjamina spun higher webs in the creek bed. Behavioral differences in leaving the web hang through the day and in hiding behavior of the spiders were also observed.

PREY SELECTION IN SYMPATRIC ORB-WEAVING SPIDERS, M. F. Haskins and D. A. Kangas, Northeast Missouri State University, 63501. Prey size selection by sympatric orb-weaving spiders may allow partial separation of niches. Live arthropods were placed in the webs of spiders and responses of the spiders were recorded. Tetragnata elongata captured prey that ranged from < 10 mg up to 125 mg (live weight). Seventy-eight percent of the observed attacks were with prey weighing < 10 mg. Prey weighing more

that 10 mg failed to elicit attacts in 51% of the experiments. Prey size selection by Aranea frondosa was less restricted that that by T. elongata, ranging from < 10 mg to > 300 but < 400 mg. Eighty-eight percent of the experiments ending in an attack by A. frondosa were with prey up to 75 mg. Seventy percent of the experiments with prey 75 mg or larger ended without an attack by A. frondosa. Neoscona benjamina selected 61% of its prey in the size range 25 to 200 mg. Attacks were not observed in 71% of the tests with prey < 25 mg. T. elongata frequented Aranea and Neoscona webs as a kelptoparasite.

THE EFFECT OF JUVENILE HORMONE TREATMENT ON ACID PHOSPHASE ACTIVITY IN SIX TISSUES OF THE MILKWEED BUG, ONCOPLETUS FASCIATUS, Cedar Beel and Dorothy Feir, Forest Park Community College, St. Louis, 63110 and St. Louis University, St. Louis, 63110. Newly ecdysed fifth instar milkweed bugs were treated with J. H. and acid phosphatase activity of six tissues was assayed at 2, 24, 48, 72, 96, 120, 144, 168, and 192 hours after ecdysis. J. H. treated measurements were compared to acetone treated controls. J. H. treated bugs exhibited significantly higher acid phosphatase activity in hemolymph, salivary gland, and testes tissue.

OXYGEN CONSUMPTION IN TETRAHYMENA PYRIFORMIS DURING NON-SYNCHRONOUS AND SYNCHRONOUS GROWTH CYCLES. VandenBoom, L.A; Nielsen P.J., Western Illinois University, Macomb, 61455. Tetrahymena pyriformis WAIL were grown to stationary phase in non-synchronous cultures. Oxygen consumption and respiratory quotients were monitored using constant volume manometry. $Q(O_2)$ values decreased as the cells approached stationary phase. The nutrient-starved stationary phase cells were resuspended in fresh growth medium and monitored during two subsequent synchronous divisions. $Q(O_2)$ values increased for the first 24 hours following synchrony.

CHANGES IN THE LOCOMOTOR BEHAVIOR OF BLUEGILLS, LEPOMIS MACROCHIRUS (RAF.) DUING ACCLIMATION IN AN OBSERVATION CHAMBER, K. S. Lubinski, K. L. Dickson, and J. Cairns, Jr., Virginia Polytechnic Institute and State University, Blacksburg, VA, 20461. As part of a study to determine the effects of pollutants on the activity, turning behavior and avoidance responses of fish, five locomotor parameters (distance traveled, time spent swimming, time spent turning, mean straight-path length, and time spent in each of four quadrants) were calculated for individual bluegills following their introduction into an open-field laminar flow observation tank. The behavior of each fish was monitored for 3 or 4 days during 10 hr simulated daylight periods. All of the parameters, and particularly those indicating general activity, were highly variable during the first two days of acclimation, indicating that at least this much time may be required before behavioral predictions can be made. (Supported by the DuPont Educational Foundation).

A NEW USE FOR AN OLD ANIMAL, THE EASTERN BOX TURTLE (TERRAPENE CAROLINA CAROLINA), R. W. Elghammer, R. E. Johnson and R. O. Swan, Knox College, Galesburg, Illinois, 61401. This species has been used as the subject in our three-year study in the following areas: heat production measured by direct calorimetry, nutrition, specific dynamic action, food and water intake, and food preferences. We have found that these turtles are resistant to disease, have a long life span, are placid, and are easily maintained in captivity. These findings support the conclusion that this animal form is a good model for use in the modern teaching and research laboratory.

HEAT PRODUCTION BY BOX TURTLES, Rodney O. Swan and Robert E. Johnson, Knox College, Galesburg, Illinois 61401. Heat produced by Eastern box turtles (Terrapene carolina carolina) was measured directly for 12 hours in a four liter Dewar flask while the animals were resting quietly in the dark at a room temperature of 25°C. During a fast of 14 days, repetitive measurements of heat production were made on days 8, 10, and 12. The mean heat production for 3 animals was 0.74 J g-1h-1 on Day 8, 0.95 J g-1h-1 on Day 10, and 0.89 J g-1h-1 on Day 12. These turtles produce heat in a consistent pattern, possibly involving regulatory systems, and may exhibit an increment in heat production after feeding.

AGE STRUCTURE AND REPRODUCTIVE SUCCESS OF COYOTES (Canis latrans) IN ILLINOIS. Brain R. Mahan, Univ. of Nebraska State Museum, Lincoln 68588 and H.T. Gier, Dept. of Anatomy and Physiology, Kansas State Univ., Manhattan, 66506. Thirty-six skulls and 18 sets of female reproductive tracts from coyotes collected 29 Dec. 1976 - 2 Jan. 1977 and 31 Jan. - 5 Feb. 1977 in SW Illinois were analyzed. Six (16.7%) of the coyotes were yearlings, 10 (27.8%) 2 years, 9 (25%) 3 years, 5. (13.9%) 4 years, and 6 (16.7%) 5+ years. Three of 15 (20%) reproductive tracts from females 2+ years old (3 yearling females deleted) had placental scars which indicated 13 pups were full-term, for a 4.3 pups/female average. The Illinois data suggest two things, 1) there is a declining coyote population because of a high old-young individual ratio, and 2) there was low reproductive success within the population in 1976. The latter agrees with recent information about the coyote population gathered by Gier (unpublished data) in the Great Plains.

LABORATORY TESTS TO EXPLORE THE USEFULNESS OF WATER TYPE BAITS FOR THE CONTROL OF WILD MICE, Charles E. Knote, Cape-Kem Laboratories, Cape Girardeau, Mo., 63701. Wild house mice, Mus Musculus, normally have been controlled with dry cereal type baits. Water type baits were considered ineffective due to the mouse's supposed ability to live for many weeks without "free" water. The Norway rat, Rattus Norvegicus, needs large quantities of "free" water every 24 hours and in a new environment will drink "free" water hours before eating. Before tests, thought was that some properly fed mice would live for days to weeks without "free" water. 5 male and 5 female mice weighing over 15 grams were individually caged and fed a balanced ration containing 12% moisture. Average humidity was 45%. Tests were replicated 2 times. The first mouse lived 2 days, the longest 15 days, the average 7¼ days. A check colony with same food plus water had no mortality. Conclusion: water type baits could be an effective mouse control agent because mice need some water. This control agent has been neglected.

FOLLICULAR DYNAMICS AND SERUM ESTROGEN LEVELS IN MICROTUS OCHROGASTER OCHROGASTER, Robert C. Prentice and Benjamin A. Shepherd, Southern Illinois University, Carbondale, 62901. Vesicular follicles were counted and measured and serum estradiol 17B concentration was determined for sexually immature, anestrous, estrous, and post coitum females. Ovaries were prepared by standard histological techniques and estradiol 17B measured by a single antibody radioimmunoassay. A relationship was found to exist between follicle diameter and serum estrogen concentration. Furthermore, the data indicate that follicle diameter can be used as reliable indicator of the reproductive status of females in this species.

QUANTITATIVE CHANGES IN AGED SPERM NUCLEI IN THE GUINEA PIG, Mary Gillenwater, W. S. Courtis*, and B.A. Shepherd, Southern Illinois University, Carbondale, 62901, and Indiana University Purdue University at Indianapolis*, Indianapolis, 46205. The effects of aging on spermatozoa from the vasa deferentia of sexually mature guinea pigs that had been hemicastrated for 25 days were monitored by quantitative interference microscopy. The nuclear dry weight of spermatozoa from the castrate side of the hemicastrated males was less than that of sperm from the intact side, however nuclear area was unchanged. Spermatozoa from intact controls were heavier than sperm from the operated sides of the hemicastrates but comparable to sperm from the intact side.

THE EFFECT OF AMYGDALIN ON PLURIPOTENTIAL CELLS, Therese Micaletti and Harold Manner, Loyola University of Chicago, Chicago, 60626. Amygdalin has been postulated to be an inhibitor of pluripotential cells. This hypothesis was tested on the fibroblasts involved in blastema formation in regenerating salamander limbs. The right forelimb of each salamander was amputated at the mid-radius-ulna area. The experimental animals were injected daily for 15 days with 2000mg/kg of Amygdalin. The control group received amphibian ringer's. The limbs were removed for study on the 16th day. Microscopic examination revealed no significant difference in the epidermal thickness of the two groups. The pluripotential fibroblasts, however, were significantly inhibited; the blastema reaching a length of only 110.84 microns compared to the normal length of 266.25 microns in the controls.

THE ACTIVITY OF THE ENZYME RHODANESE IN TUMOROUS MOUSE TISSUES, Mary Poletti and Harold Manner, Loyola University of Chicago, Chicago, 60626. Rhodanese activity was determined spectrophotometrically in supernatants from crude tissue homogenates of selected tissues isolated from male mice (strain BABL/cJ, Jackson Laboratories, Maine) with transplanted axillary sarcomas. The control group included male mice of the same strain injected with the vehicle. Activity was high in the liver, with kidney showing moderate activity and brain and muscle tissues having lower activities. The tumor tissue, which has been postulated to be devoid of rhodanese activity, was found to have activity as high as brain tissue and significantly higher than muscle tissue.

CELL BODY MAPPING IN GANGLIA OF SYPHACIA OBVELATA (NEMATODA:OXYURIODEA), Dennis M. McNair, Southern Illinois University-Carbondale, Carbondale, 62901
A map of the cell bodies in the anterior ganglia of Syphacia obvelata, a pinworm of mice, has been prepared using serial sections stained with toluidine blue O. The properties of the stain allow differentiation of nerve cells from other cells in and around the ganglia, and the number and spatial relation of cells are consistent enough to allow identification of individual cells from specimen to specimen. Putative neurotransmitters within these cells are being investigated using a formaldehyde induced fluorescence technique.

A MODEL FOR THE METABOLISM OF ETHANOL IN THE LIVER, Carol Axtell and Robert Rutledge, Lewis and Clark Community College, Godfrey 62035 and Southern Illinois University, Edwardsville, 62025. The basic biochemical model of alcohol metabolism involves three interrelated enzyme pathways -- those of alcohol dehydrogenase, catalase and the microsomal ethanol-oxidizing system. A mathe-

matical model is proposed to explain the biochemical data. The process of developing the mathematical model is discussed. The behavior predicted by the model is compared with real experimental data from studies of liver metabolism.

THE EFFECTS OF SMOKING ON EXFOLIATION FROM THE BUCCAL MUCOSA, Henry D. Detwiler, A.J. Pappelis, Joan Slobin, Joseph Corvallis, John Schoenberger, Michael Ginster, Richard Fears, Kevin Turner, and Christine K. Pappelis, Southern Illinois University - Carbondale, 62901. Two studies were conducted to determine means for various cell types observed in buccal smears of smokers and nonsmokers. In a study of 123 males, the number of anucleate cells observed in buccal smears varied. The order from greatest to least was as follows: smokers, former smokers that had quit for less than 5 years, former smokers that had quit for 5 years or more, and those who had never smoked. For the Cell Development Index and Maturation Index, means for smoking and non-smoking donors were similar. Means for the Karyopyknotic Index distinguished smokers from non-smokers. Means for cellular and nuclear area were similar in both groups. Data from a second study of 22 males showed similar results.

EFFECT OF CHRONIC TREADMILL EXERCISE UPON MYOCARDIAL ANOXIC RESISTANCE, David L. Cooper, Loren G. Martin and Jasper Freeman, University of Illinois, Department of Basic Sciences at the Peoria School of Medicine, Peoria, 61605 and Department of Physiology at the Medical Center, Chicago, 60612. Female 250 g CD strain albino rats were maintained on a synthetic completely-fortified thyroxine-free diet and tap water ad lib. at a laboratory temperature of $70\pm2°F$ with a daily lighting schedule of 12 light/12 dark. Control and experimental animals were maintained in the laboratory for a 6-week period, during which time the experimental rats were placed on a rodent treadmill and exercised for a 45-minute period at 30 m/minute daily. After the 6 week period, hearts were removed from all animals, and an in vitro right ventricular anoxia resistance test revealed that no significant change in this myocardial parameter had been effected via the chronic exercise period. This finding differs markedly from that seen after chronic altitude exposure.

EFFECT OF SODIUM DEFICIENCY AND CATECHOLAMINES ON RENIN RELEASE AND C-AMP CONTENT OF RAT RENAL CORTICAL SLICES. Genaro A. Lopez, Dept. of Biology, Loyola University of Chicago, Chicago, Illinois 60626. The effect of L-norepinephrine (NE) on renin release (RR) by kidney slices of sodium-replete (SR) and sodium-deficient (SD) rats was studied In Vitro. Addition of NE doses from $2X10^{-9}M$ to $2X10^{-4}M$ to slices from SR rats significantly increased RR at a concentration of $2X10^{-7}M$. Conversely, doses of NE from $2X10^{-12}M$ to $2X10^{-7}M$ added to slices from SD rats significantly increased RR in a dose-related fashion. At $2X10^{-4}M$ NE significantly inhibited RR in the latter group. This inhibition was converted to stimulation upon adding the alpha-adrenergic blocking drug phentolamine. Phentolamine by itself was ineffective. The changes in RR produced by NE were accompanied by parallel changes in the c-AMP content of the slices. These data indicate that,
1) sodium deficiency potentiates the RR responses to NE stimulatin,
2) RR stimulation by low NE doses is beta-receptor- and c-AMP-mediated and,
3) RR inhibition by high NE doses may be alpha adrenergic receptor-mediated.

EFFECT OF INJECTED IRON ON THE ACCUMULATION AND ELIMINATION OF DIETARY GOSSYPOL IN SELECTED ORGANS OF THE RAT, Jim N. Tone and Reed Jensen, Illinois State University, Normal, 61761. A study was made to determine the effect of injected iron on the pattern of accumulation and elimination of dietary gossypol from selected organs of rats. The animals received a gossypol diet (80 per cent ground commercial rat chow and 20 per cent cottonseed meats containing 0.98 per cent free gossypol) and weekly injections of iron

sorbitex (10 mg of iron/kg of body weight) or saline. At the end of 28 days one half of each group was maintained on a gossypol free diet for an additional 28 days. Organs (liver, spleen, kidney, heart and lungs) from rats fed the recovery diet exhibited reduced concentrations of free and bound gossypol. Bound gossypol concentration in the liver among saline or iron injected animals displayed the greatest reduction. There was no evidence that supplemental iron affected gossypol elimination in the liver and spleen.

GLUGOREGULATION AFTER PARTIAL HEPATECTOMY IN FASTING RATS, Robert P. Cornell, Northeast Missouri State University, Kirksville, 63501. This study determined in fasting rats just following (0 hr.) and 48 hr. after partial (70%) hepatectomy: 1) the conversion rate of amino acids into glucose, i.e., gluconeogenesis, 2) the contribution of the kidneys to gluconeogenesis, and 3) the uptake rate of blood glucose. The in vivo conversion of 14C-alanine into blood glucose was significantly decreased in hepatectomized rats compared to surgical sham controls at both 0 hr. (27%) and 48 hr. (18%). The presence or absence of renal circulation during the 30 min. test did not alter this conversion so the kidneys seem not to contribute to gluconeogenesis after partial hepatectomy. Glucose clearance was significantly (42%) increased in hepatectomized rats compared to surgical sham controls only at 48 hrs. A possible conclusion is that hepatic gluconeogenesis may not be depressed at 48 hrs. but that increased glucose uptake may be responsible for the apparent decreased conversion of 14C-alanine into blood glucose.

SENECTUOUSLY-RELATED CHANGES IN THYROIDAL FUNCTION IN THE RAT, Loren G. Martin and David L. Cooper, University of Illinois, Department of Basic Sciences at the Peoria School of Medicine, Peoria, 61605 and Department of Physiology at the Medical Center, Chicago, 60612. Competitive protein binding analyses (T_4-CPB) and radioactive triiodothyronine uptake tests (RT_3U) were conducted on rat serum to determine the efficacy of utilizing these tests in the rat. Increases in serum thyroxine are detected by the T_4-CPB test, and decreases are reliably quantitated by both the T_4-CPB and RT_3U tests. Groups of variously-aged rats (2, 12, 24 and 40 months of age) were then evaluated using these thyroidal function tests. While both T_4-CPB and RT_3U values demonstrated significant decreases in thyroidal function in the rat as a result of increasing age, the highest correlation was seen between the decrease in free thyroxine indices (FTI) and increasing age.

EFFECTS OF THYROXINE ON THE GROWTH AND RESORPTION OF REGENERATED TAIL TISSUE OF RANA PIPIENS, C. Thomas Wiltshire, Culver-Stockton College, Canton, MO 63435. A quantitative examination of the effects of DL thyroxine (T_4) on the growth and resorption of intact and regenerated tadpole tail tissue of R. pipiens was made. Half the length of the tails of R. pipiens larvae were excised at stages I, III, V, and X. The regenerating animals were treated with 50 µg/l of T_4 after 2, 4, 7, and 10 days of regeneration. Regenerating tail tissue responded to T_4 with a transitory stimulation of growth followed by resorption. The proximal non-regenerated tail tissue showed resorption before the regenerated tissue. The developmental history of the tail tissue influences whether T_4 promotes its growth or resorption.

EFFECT OF LATERAL HYPOTHALAMIC LESIONS ON SERUM CHOLESTEROL IN THE RAT, Glenn F. Spaulding and Robert H. Buchholz, Monmouth College, Monmouth, Il. 61462. Bilateral lesions of the lateral hypothalamus resulted in a loss of weight and reduction of serum cholesterol in the rat, (Sprawgue-Dawley strain). Serum cholesterol samples were compared in control, sham and lesioned groups every four days for twenty days. From the eighth day until the twentieth day the serum cholesterol was statisticly different ($p < .05$) in the lesioned group.

SDS-POLYACRYLAMIDE GEL PROFILES OF (^{3}H)-LEUCINE-LABELED PROTEINS OF NUTRITIONALLY STARVED G1-PHASE TETRAHYMENA PYRIFORMIS. Luthin, G.R.; Nielsen, P.J., Western Illinois University, Macomb 61455. Tetrahymena pyriformis WA1L were synchronized by nutrient starvation, then resuspended in fresh growth medium. The proteins of the synchronized cells were pulse-labeled at various times during G1 phase with (^{3}H)-leucine. Molecular weights of the labeled proteins were determined by SDS-polyacrylamide gel electrophoresis. The protein bands were individually analyzed for radioactivity by liquid scintillation. 80% of the counts were from proteins of less than 50,000 molecular weight.

HISTOLOGIC STAINING IN AN ELECTRIC FIELD, Michael Capek and Harold M. Kaplan, Southern Illinois University, Carbondale, 62901. A pilot study was undertaken to test whether improvements, especially in time, could be made by substituting a high voltage electric field for the ordinary passive diffusion method of staining histologic preparations. High voltage DC power supplies were experimented with to produce stain penetration in human liver tissue sections. The results to date have produced staining equal to, but not surpassing in quality, classically stained tissue. If this technique could ultimately prove effective, it would permit marked shortening of staining time of tissue required especially for pathologists.

RECENT HERPTOLOGICAL RECORDS FOR WESTERN ILLINOIS INCLUDING A RELIC POPULATION OF THE FOUR-TOED SALAMANDER, HEMIDACTYLIUM SCUTATUM, P. Schramm and R. M. Nordgren, Knox College, Galesburg, Illinois 61401. This paper reports new herptological records for Knox, Henderson and Bureau County in Western Illinois, including the occurrence of a small but persisting, relic population of the four-toed salamander Hemidactylium scutatum on the Knox College Biological Field Station located 4 miles south of Victoria in Knox County. In addition to several new county records, significant range extensions are reported and documented for Eumeces fasciatus, Ambystoma maculatum, and two races of Thamnophis sirtalis, plus fill-in records for Elaphe obsoleta and Lampropeltis caligaster on the northern edges of their respective distributions in the state. All specimens have been deposited in the Knox College Vertebrate Collection (here designated KVC).

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AN ASSESSMENT OF WATER QUALITY IN THE SPOON RIVER, PART 1

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ABSTRACT

The physical and chemical water quality characteristics of the Spoon River covering a period of 2 years from June 1971 through May 1973 are presented in this report. The river water temperature exhibits distinct annual cyclic fluctuations. The dissolved oxygen concentration shows a remarkable degree of inverse relationship to water temperatures. The nitrate concentrations in the Spoon River were the highest at Modena and decreased progressively downstream. The nitrate-nitrogen concentrations in the Spoon River at Havana and Seville met the Illinois Pollution Control Board standard of 10 mg/l as nitrogen at all times, whereas the limit was exceeded at the other three sampling locations about 5 percent of the time. The nitrate-nitrogen contribution to the river from the watershed ranged from 16.5 lbs/ac/yr at Modena to 10.0 lbs/ac/yr at Havana.

INTRODUCTION

In order to assess the water quality characteristics of the Spoon River, which is tributary to the Illinois River, the Water Quality Section of the Illinois State Water Survey conducted a water quality study commencing on June 1, 1971, and terminating on May 29, 1973. Water samples collected at weekly intervals from five locations were examined to determine the physical and chemical quality characteristics and to enumerate bacterial and plankton densities. Continuous weekly determinations were made for temperature, dissolved oxygen, turbidity, pH, alkalinity, hardness, nitrate, ammonia, Kjeldahl nitrogen, chemical oxygen demand, total suspended solids, total dissolved solids, total dissolved phosphate, and dissolved orthophosphate. Determinations on every third weekly sample were made for calcium, magnesium, silica, total iron, filterable iron, manganese, and sulfate.

The objectives of Part 1 of this report are to present in a concise form the weekly physical and chemical water quality data with the exception of phosphorus, and to examine the seasonal variations in the water quality characteristics. A comparison of the river water quality with the stream standards adopted by the Illinois Pollution Control Board (IPCB),

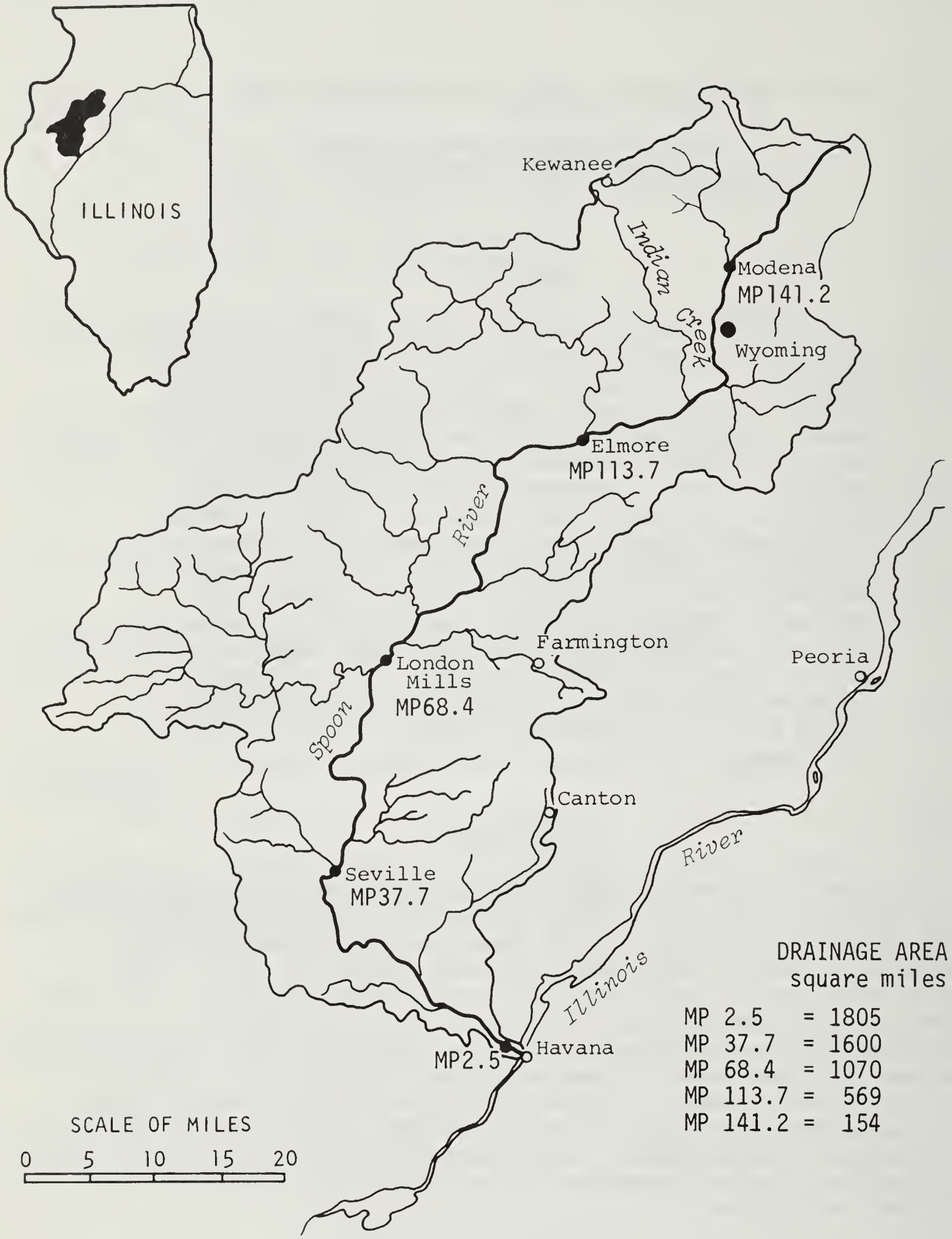

FIGURE 1.--Spoon River basin showing sampling stations.

where applicable, is also presented. Evaluation of the bacterial and algal quality characteristics has been dealt with separately by Lin et al. (1973,1974). Part 2 of this report includes the weekly phosphorus data and the chemical quality determinations made once every three weeks.

STUDY AREA

The Spoon River, with a drainage area of about 1805 square miles, extends approximately 161 miles in length from its confluence with the Illinois River in the vicinity of Havana. Starting from its two sources, the East Fork and the West Fork, it flows in an almost southerly direction. In addition to its origin, the principal tributaries include Indian, Walnut, Court, Cedar, and Big Creeks. The slope of the main stem of the river ranges from 4 feet per mile in the vicinity of its confluence with the East and West Forks to 0.6 foot per mile near its mouth (0.076 to 0.011 percent).

Figure 1 shows the Spoon River watershed and the five sampling locations on the main stem. Information on the river watershed areas at each of these locations is also noted on Figure 1.

Sixteen waste treatment plants discharge effluents within the basin. Two of these serve the communities of Kewanee and Canton with populations of 15,800 and 14,200 persons, respectively. The rest serve communities with populations less than 3200 persons.

Flow gages for the Spoon River are maintained and operated by the U.S. Geological Survey at Seville and London Mills. The hydrographs of river discharges at these two locations for the period of study are shown in Figures 2 and 3, respectively. The mean streamflows in cubic feet per second (cfs) at Seville and London Mills are also noted. During the first year of observations, the streamflows were much below normal values. During the second year, the flows were higher than long-term averages.

There are no flow data by direct measurements for the other three sampling stations. However, flow records for these stations were synthesized by the method suggested by Singh (1971) employing all of the available flow data for the Spoon River at Seville and London Mills, and the flow data for Indian Creek at Wyoming in the Spoon River basin.

WATER QUALITY

Individual chemical determinations for the samples were analyzed by procedures outlined in Table 1. Results of determinations are expressed as milligrams per liter (mg/l) except for temperature, pH, turbidity, and flow. Temperature is in Celsius units and turbidity is in Jackson turbidity units (Jtu). Flow values are given as cubic feet per second (cfs).

Results of analysis for means and ranges for the water quality parameters considered in this report and for streamflows are shown in Table 2. An attempt was made to delineate the seasonal changes in the values. The data were classified into biannual, triannual, and quadriannual

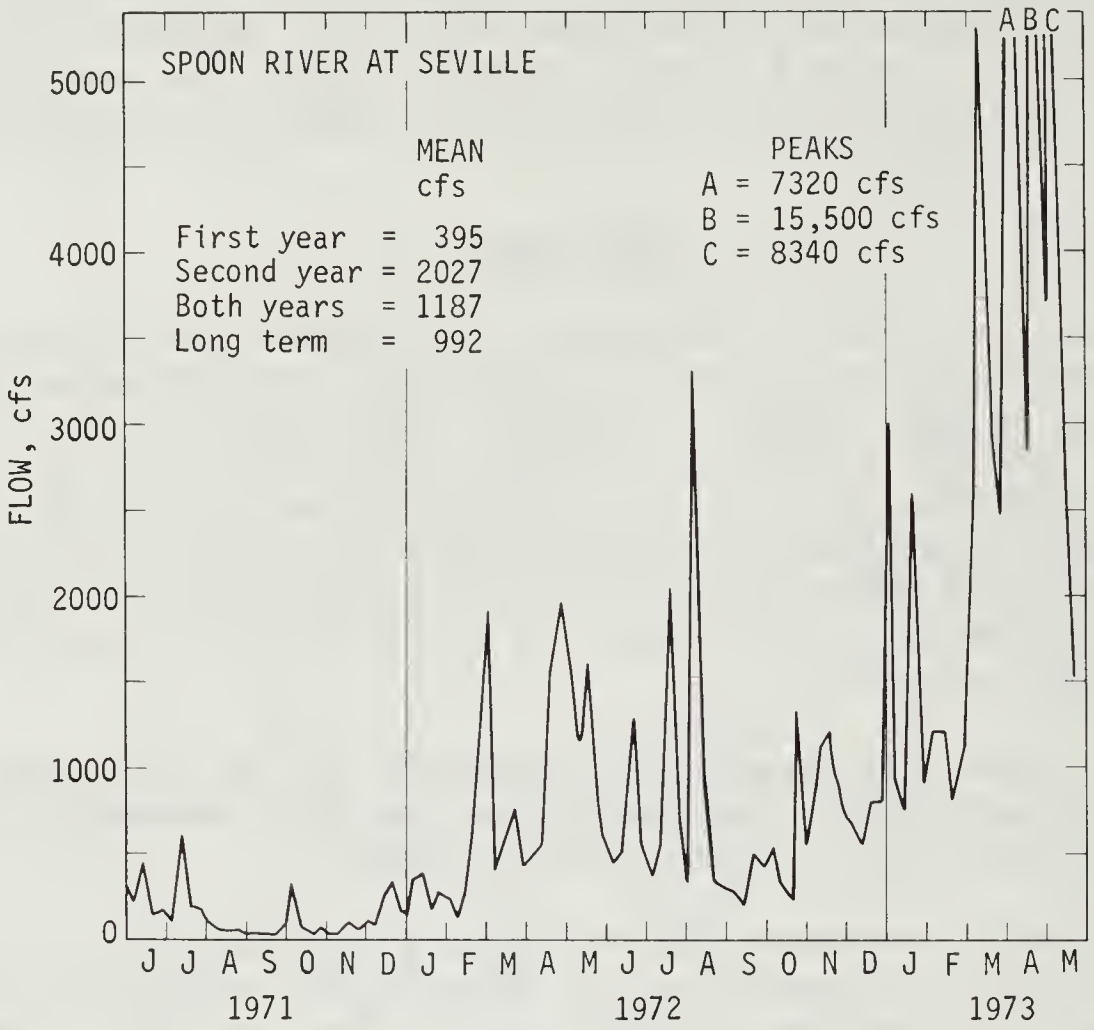

FIGURE 2.--Hydrograph for Spoon River at Seville.

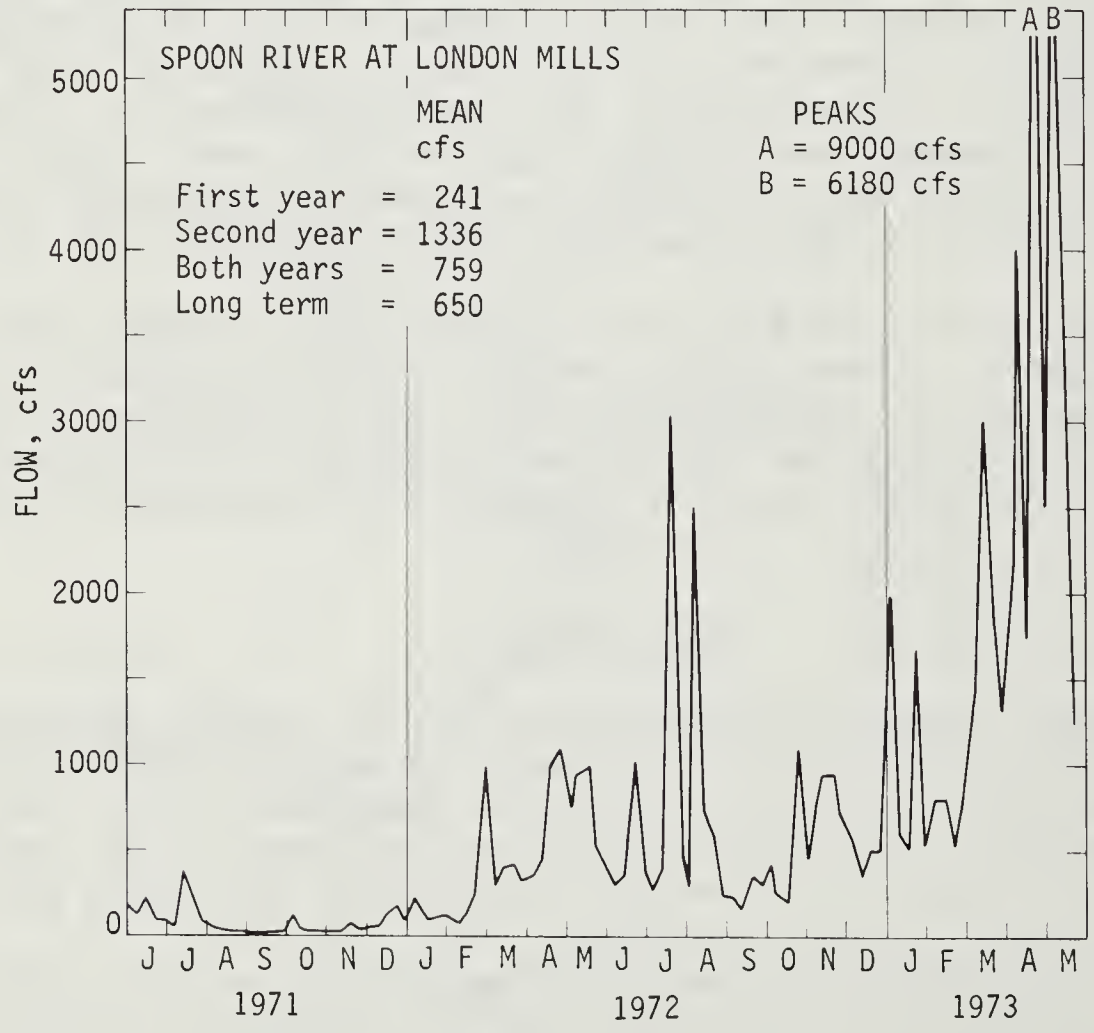

FIGURE 3.--Hydrograph for Spoon River at London Mills.

groupings, and the central tendencies of the parameters were evaluated. Apart from the distinct seasonality in temperature and dissolved oxygen, no periodic fluctuations could be discerned in any of the water quality parameters. Because data for the Spoon River are for only two years, long-term fluctuations in the parametric values, if any, could not be detected.

TABLE 1. Analytical Procedures

Determinations	Analytical procedures
Dissolved oxygen	Azide modification of Winkler method
Alkalinity (as $CaCO_3$)	Titration with 0.02N H_2SO_4 to a pH of 4.5
pH	pH meter
Turbidity	Evelyn photometric colorimeter
Hardness	EDTA titration
Nitrate	Chromotropic acid method
Ammonium-N	Distillation and nesslerization
Kjeldahl nitrogen-N	Digestion and titration
Chloride	Mohr
Chemical Oxygen Demand	Dichromate reflux method
Total dissolved solids	Residue on filtration and evaporation
Suspended solids	Gravimetric method

Temperature and Dissolved Oxygen. The IPCB stipulates water temperature limitations at representative locations in the main river not to exceed 15.5°C in the months of December through March and 32.2°C in the months of April through November. Figure 4 shows the temporal variations in temperature in the Spoon River at Havana. The data points represent the monthly means of observations. The distinct annual cyclic fluctuations in the river water temperature are clearly discernible. The temperature plots for other sampling locations are very similar to that for Havana. As there is no thermal discharge into the river, the variations in stream temperature are due solely to natural causes.

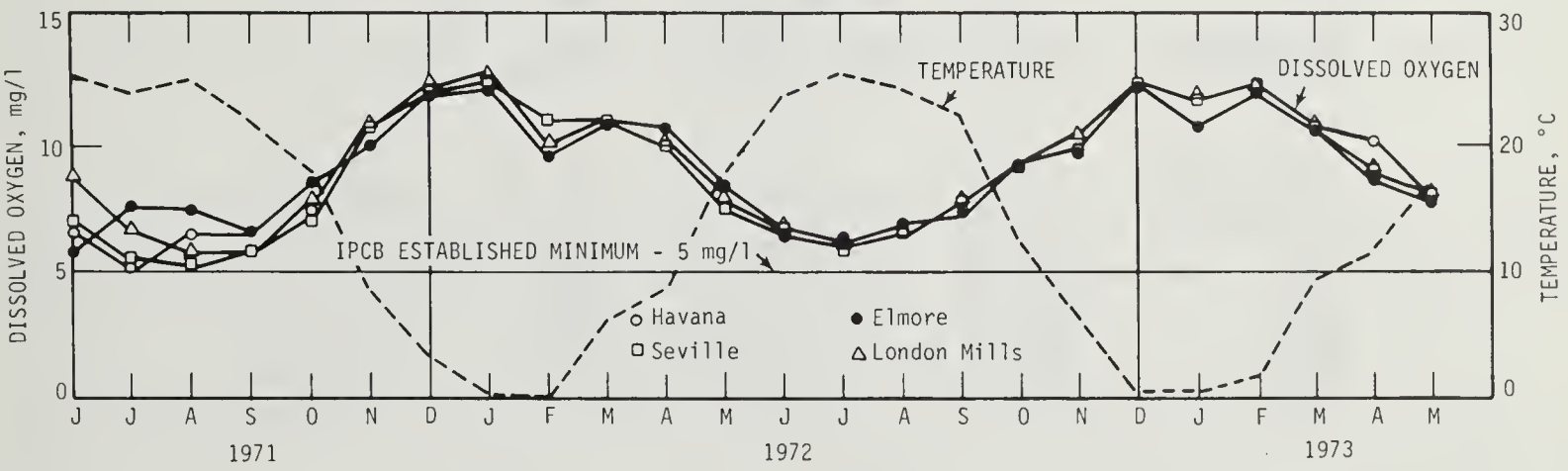

FIGURE 4.--Temporal variations in temperature and dissolved oxygen.

Figure 4 also shows the temporal variations of dissolved oxygen (DO) at the five locations. Though the monthly averages for DO concentrations

TABLE 2. Water Quality Characteristics of Spoon River at Five Locations

Parameter	Havana Mean	Havana Range	Seville Mean	Seville Range	London Mills Mean	London Mills Range
Temperature	13.3	0.0-25.6	12.7	0.0-28.0	12.4	0.0-27.2
DO	8.9	3.5-12.1	9.0	4.4-13.0	9.2	3.1-13.4
Turbidity	252.0	6.0-447.0	232.0	3.0-3470.0	169.0	5.0-2600.0
pH	-	7.34-8.25	-	7.52-8.50	-	7.50-8.57
Alkalinity	222.0	83.0-277.0	225.0	98.0-310.0	243.0	92.0-341.0
Hardness	335.0	110.0-409.0	332.0	147.0-478.0	340.0	124.0-478.0
Kjeldahl-N	2.0	0.01-20.30	1.65	0.01-12.4	1.48	0.01-8.80
Nitrate-N	3.68	0.0-8.85	4.03	0.0-10.0	4.65	0.0-11.0
Ammonium	0.18	0-3.70	0.15	0-2.87	0.15	0-1.86
Chloride	21.8	5.0-45.0	22.9	8.0-44.6	29.6	7.6-99.0
COD	32.3	5.1-327.0	31.9	4.7-347.0	23.7	3.5-147.0
TDS	479.0	203.0-736.0	466.0	191.0-715.0	482.0	189.0-672.0
TSS	388.0	1.0-7405.0	332.0	0.0-4270	249.0	1.0-4305.0
Flow	1286	32-15,7000	1,187	28-15,500	759	18-9,000

Parameter	Elmore Mean	Elmore Range	Modena Mean	Modena Range
Temperature	12.1	0.0-23.7	12.3	0.0-28.0
DO	9.2	4.3-12.3	9.3	0.4-13.8
Turbidity	208.0	5.0-386.0	146.5	6.0-2600.0
pH	-	7.1-8.3	-	7.42-8.52
Alkalinity	256.0	64.0-310.0	265.0	69.0-360.0
Hardness	335.0	95.0-395.0	346.0	95.0-467.0
Kjeldahl-N	1.63	0.01-10.8	1.85	0.01-11.30
Nitrate-N	5.6	0.0-11.8	6.0	0.4-9.4
Ammonium	0.18	0-2.37	0.49	0-3.58
Chloride	37.5	3.0-193.0	63.1	7.4-266.0
COD	28.0	1.4-380.0	25.5	0.7-240.0
TDS	481.0	155.0-813.0	532.0	193.0-775.0
TSS	242.0	1.0-3304.0	214.0	4.0-328.0
Flow	410	9-4,718	108	2-1,248

at these locations were greater than the 5.0 mg/l minimum limit stipulated by the IPCB, very few individual observations were found to be less than 5.0 mg/l. A probability distribution for the occurrence of DO concentrations at all the sampling locations is shown in Figure 5. The DO concentration is likely to be less than the IPCB limit of 5 mg/l for about 5 percent of the time. As shown in Table 2 and Figures 4 and 5, there is very little spatial variation in the DO concentration along the river.

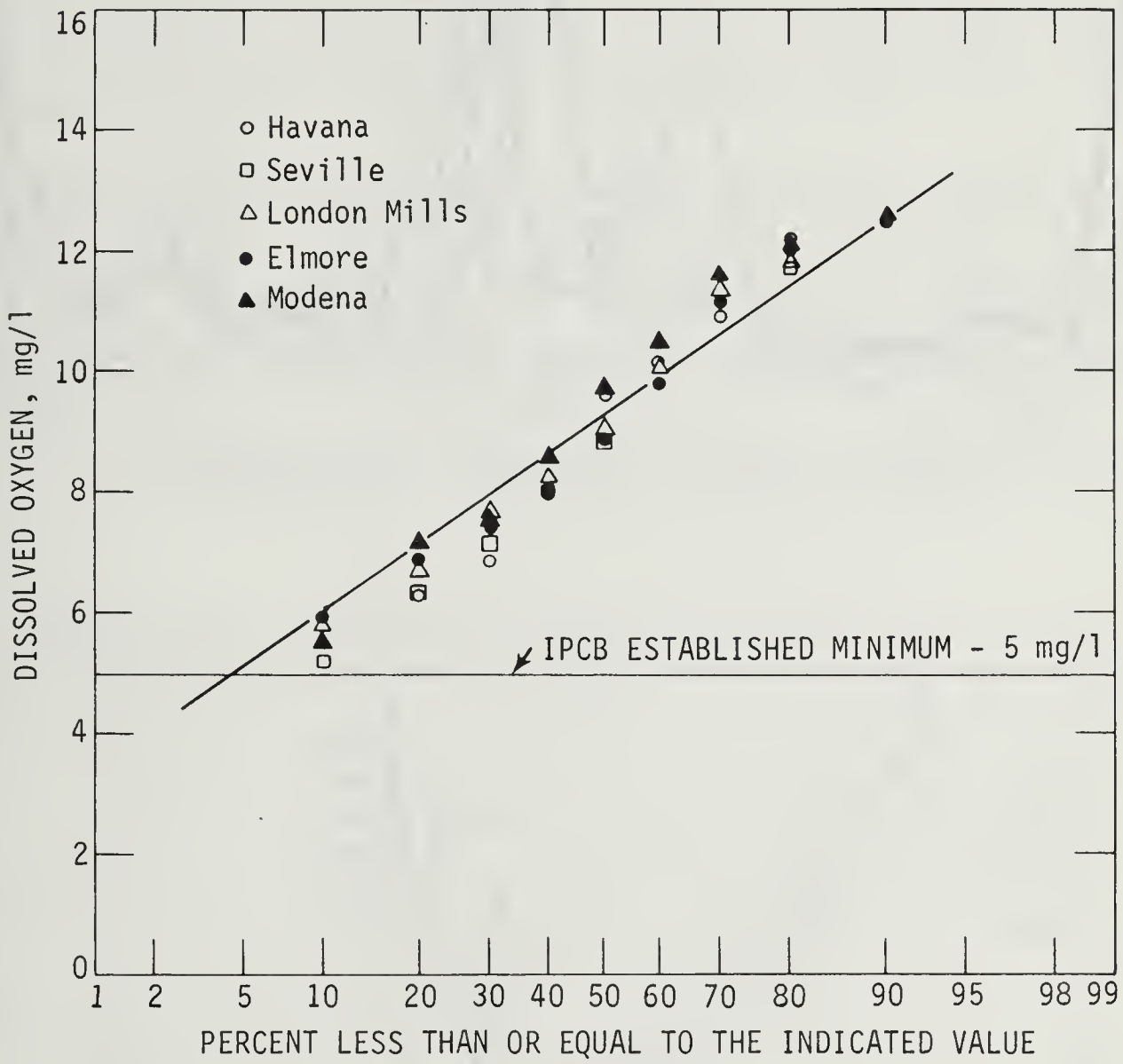

FIGURE 5.--Cumulative probability distribution of dissolved oxygen.

The oxygen resources of the Spoon River do not appear to be unduly stressed. There are two major waste treatment plants on the stream. The Kewanee waste treatment plant is located at the headwaters of the Spoon River, about 20 miles upstream of the sampling station at Modena. This is the only location where a minimum DO of 0.4 mg/l was observed. The minimum observed DO at all other sampling stations was 3.1 mg/l or more. Even so, only in 4 out of a total of 103 observations at Modena was the DO concentration less than the IPCB standard. The Canton waste treatment plant discharges into a tributary to Spoon River, so its impact on the main stem of the Spoon River is minimal.

Turbidity and Suspended Solids. Soil erosion and the concomitant sedimentation are dependent on factors such as intensity and duration of rainfall, soil characteristics, slope of the drainage basin, and cropping

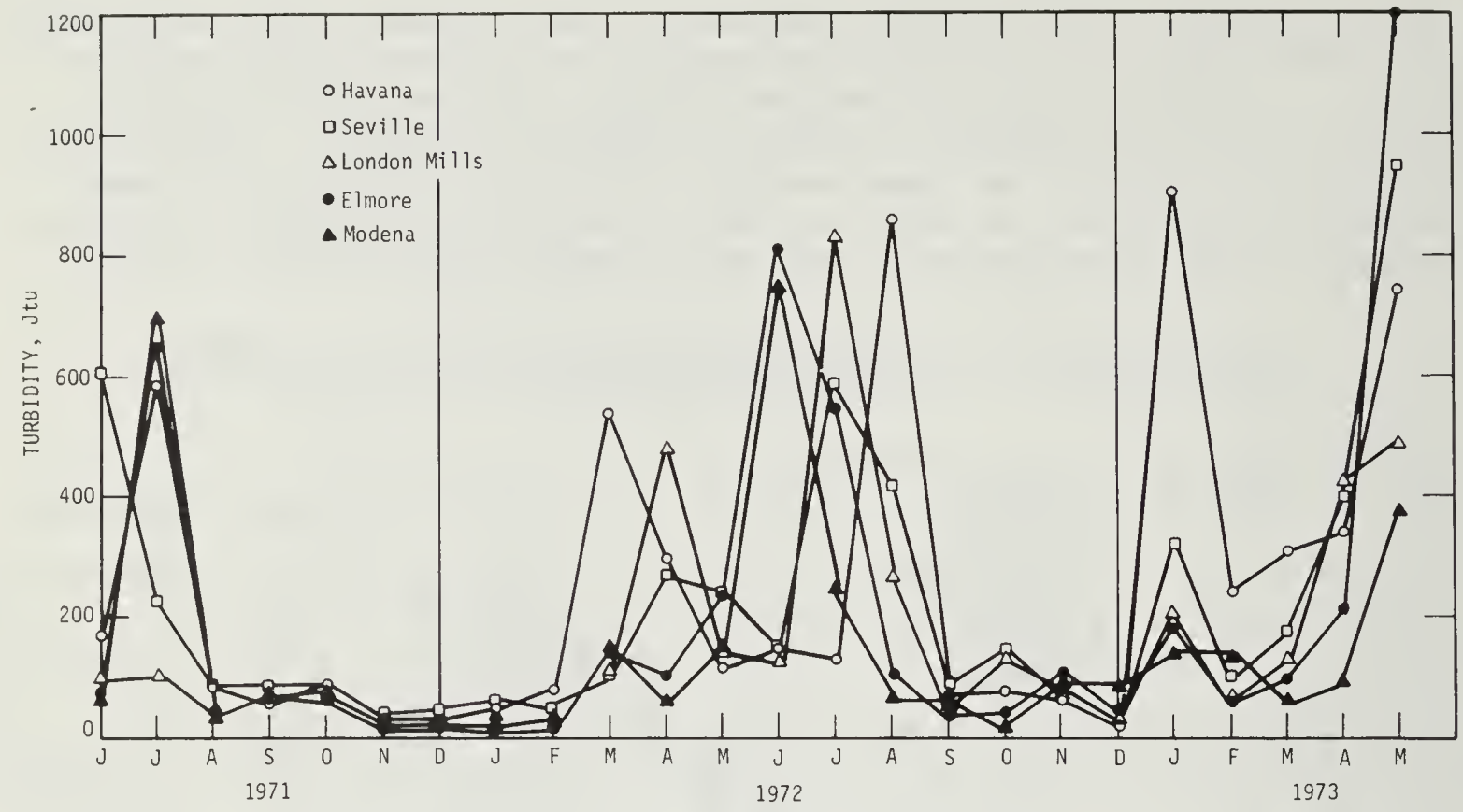

FIGURE 6.--Temporal variations of turbidity.

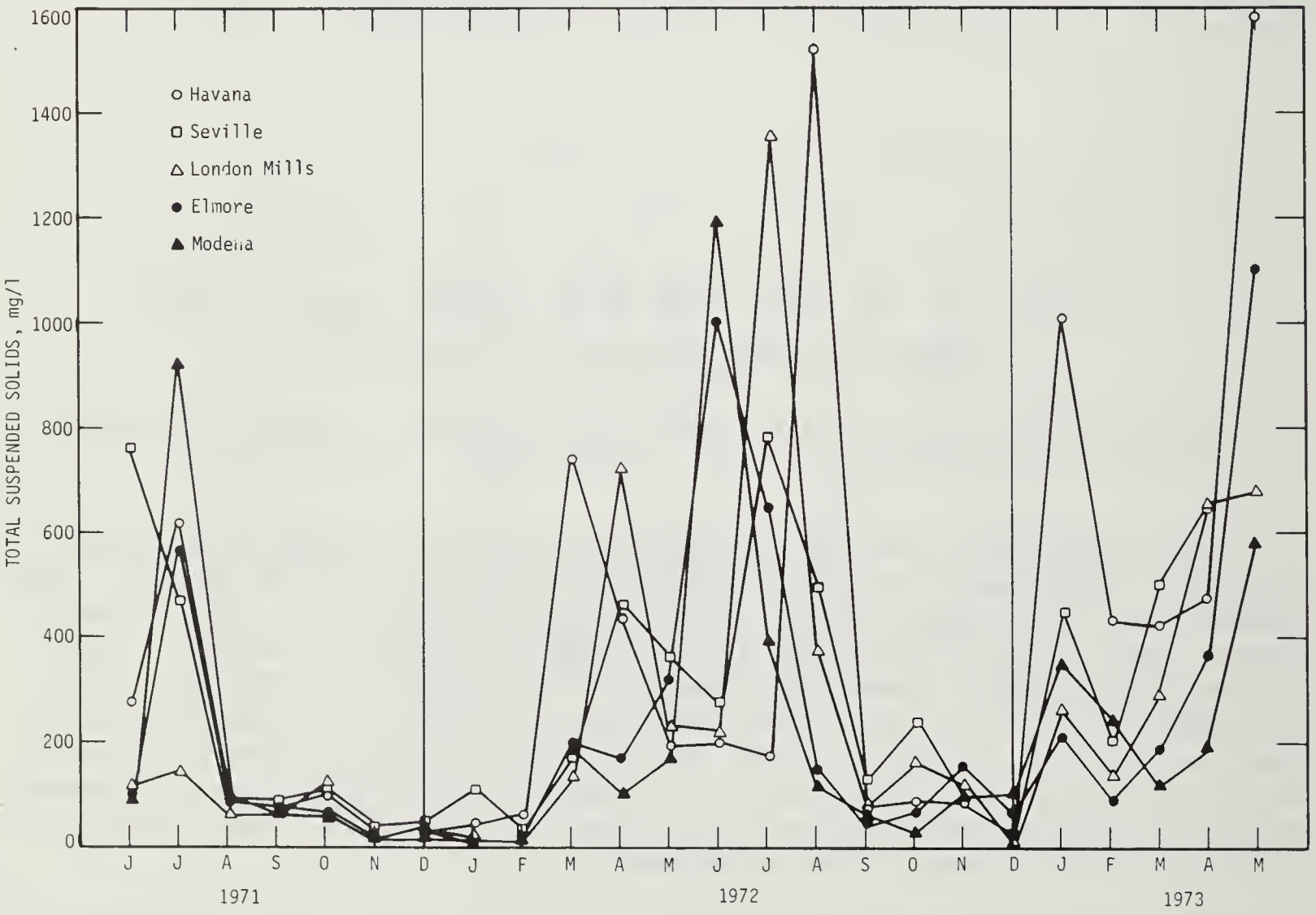

FIGURE 7.--Temporal variations of total suspended solids.

practices. Not only does erosion result in a loss of valuable topsoil from agricultural lands, it also has deleterious effects on water quality, recreational enjoyment, fish propagation, and the management of reservoirs.

The temporal variations in turbidity for the Spoon River at the five sampling locations are shown in Figure 6. The turbidity is generally very high except during periods of very low streamflow, that is, when the flow is primarily base flow or interflow. During periods of flood conditions, the turbidity in the river at the lower reaches was well above 800 Jtu. Comparison of Figure 6 with Figures 2 and 3 reveal that the river turbidity closely parallels the flow in the river.

The spatial and temporal variations and the probability distributions of suspended solids in the Spoon River are shown in Figures 7 and 8, respectively. It is not surprising that the variations in suspended solids closely follow the variations in flow and turbidity. The probability of exceeding a given concentration of suspended solids increases along the downstream direction from Modena to Seville. The trend is reversed at Havana mainly because of the partial sedimentation taking place as a result of the backwater effect created at the confluence of the Spoon River with the Illinois River.

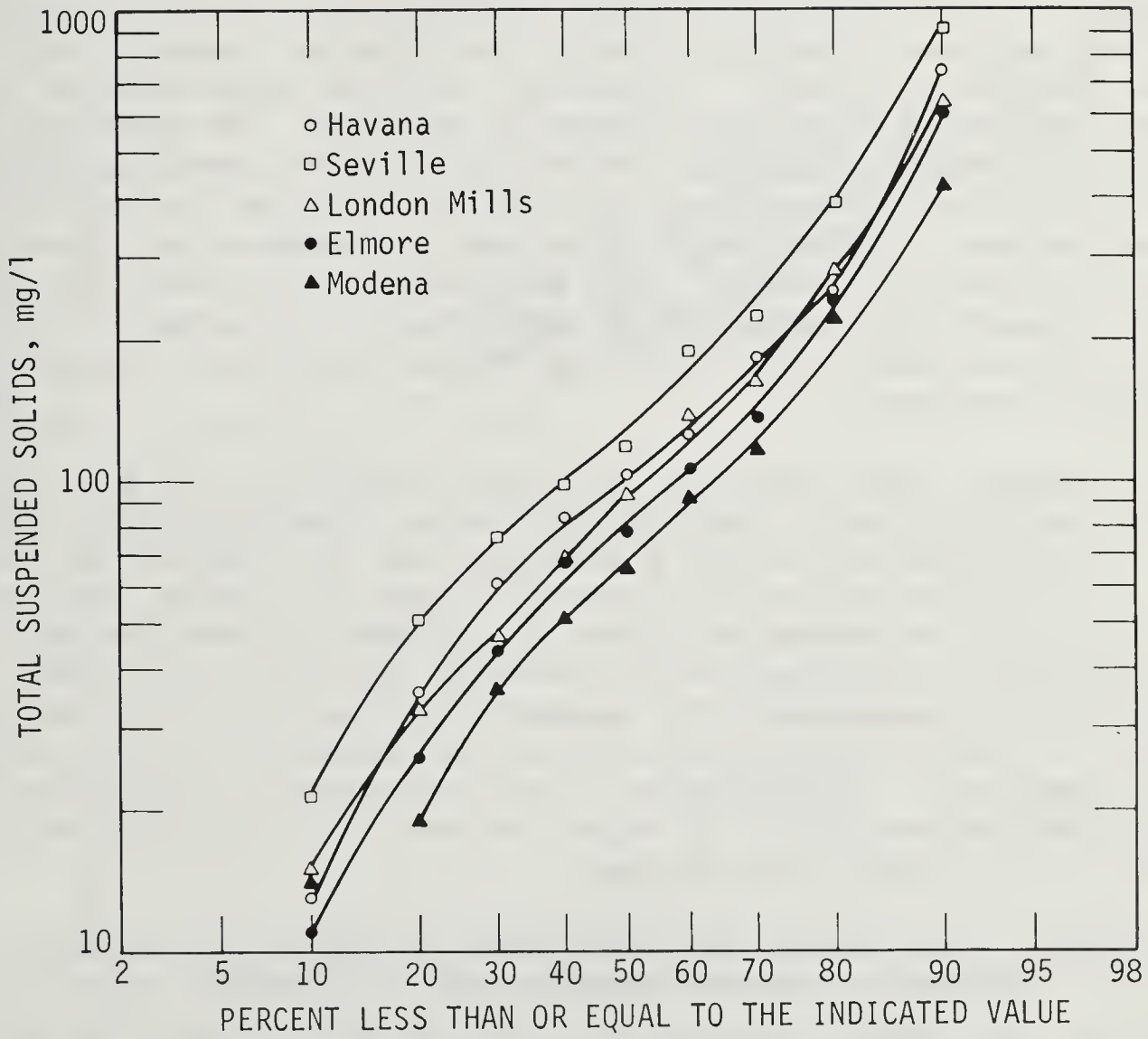

FIGURE 8.--Cumulative probability distribution of suspended solids.

Mineral Quality. The pH of Spoon River water samples varied from 7.1 to 8.57. As the pH values are reciprocals of the logarithm of hydrogen ion concentrations in the water samples, arithmetic means of pH values were not computed. The range of observed values shown in Table 2 was well within the IPCB stipulated range of 6.5 to 9.0.

Spoon River, typical of midwestern stream waters, is rich in alkalinity and hardness. The IPCB does not stipulate a standard for alkalinity in natural waters. High alkalinity waters have been reported to have a distinctly unpleasant taste as they are generally associated with high values of pH, hardness, and dissolved solids (McKee and Wolf, 1963). The temporal variations in alkalinity for three sampling stations are shown in Figure 9. Table 2 shows that the mean values for alkalinity tend to decrease in the downstream direction, having the highest value of 265.0 mg/l at Modena and the least value of 222.0 mg/l at Havana. In Figure 10, a similar stratification in alkalinity values for different percentiles of occurrence is also noticeable.

Chloride and sulfate are the predominant anions causing what is known as 'permanent hardness.' Because of the mineral taste caused by the chloride ion, and the cathartic effect of the sulfate, particularly on transient population, the IPCB limits each of these constituents to 500 mg/l in natural waters. However, there is no specific limit set for hardness.

Figure 11 indicates that, except during periods of very low flow as in the fall and winter months of 1971, the chloride concentrations remained well below 50 mg/l. In general, chloride concentration levels were well within the stipulated limits of the IPCB. The cumulative probability distributions of chloride values for the five sampling locations (Figure 12) exhibit a log-normal distribution with two distinct statistical populations. The temporal variations in hardness for three locations are shown in Figure 13. The mean values of observations along the river appear to be comparable in magnitude. The probability of occurrence of hardness values shown in Figure 14 exhibits the same trend for all five stations.

For drinking water supplies, an upper limit of 500 mg/l for total dissolved solids is set on the basis of taste thresholds (McKee and Wolf, 1963). The IPCB has stipulated a limit of 1000 mg/l for TDS in natural waters. Total dissolved solids observed in the Spoon River were well below this limit, as shown in Figure 15. Except for the observations at Modena during the period of June to November 1971, the TDS values appear to be of similar magnitude. The cumulative probability distribution of TDS in Figure 16 again confirms that all the TDS values belong to a single statistical population. Urbanization in the headwaters of the Spoon River increases the concentrations of chlorides and total dissolved solids there compared with the downstream reaches.

Nitrogen. The concern for nitrogen as a contaminant in water bodies is twofold. Because of adverse physiological effects on infants and because the traditional treatment processes do not remove nitrate, concentrations of nitrate plus nitrite as N are limited to 10 mg/l in public water supplies. Secondly, a concentration in excess of 0.3 mg/l is

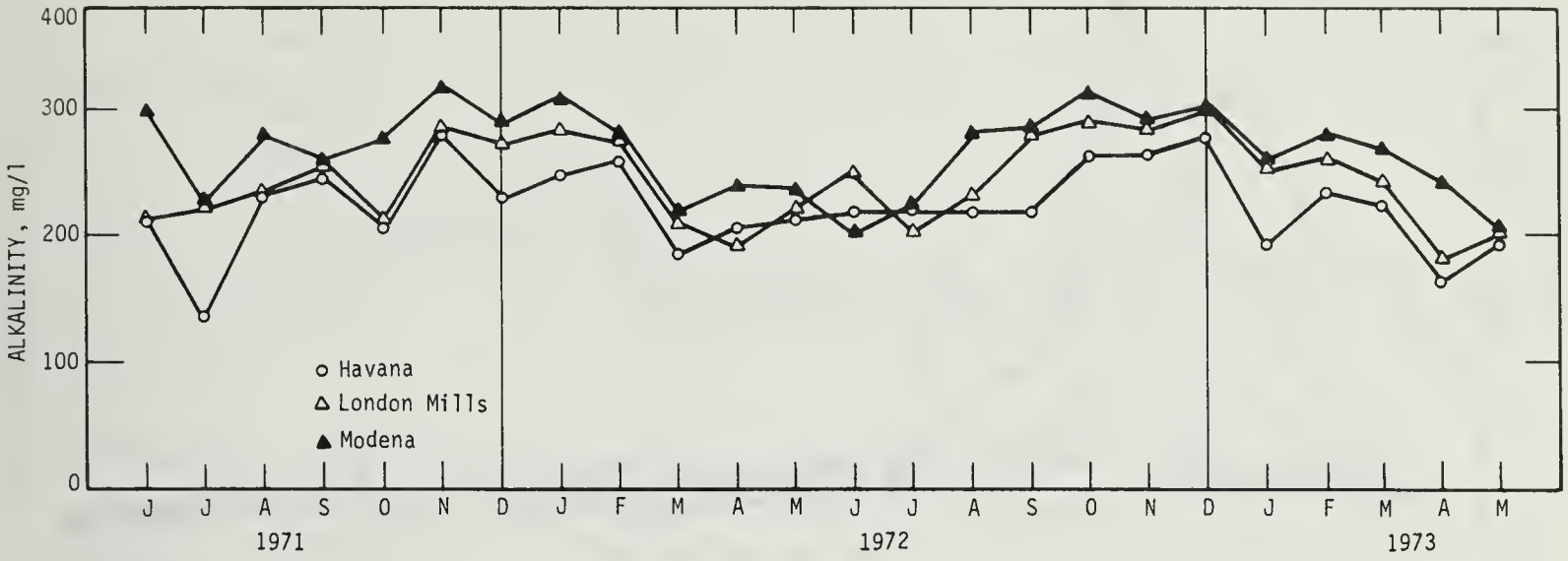

FIGURE 9.--Temporal variations of alkalinity.

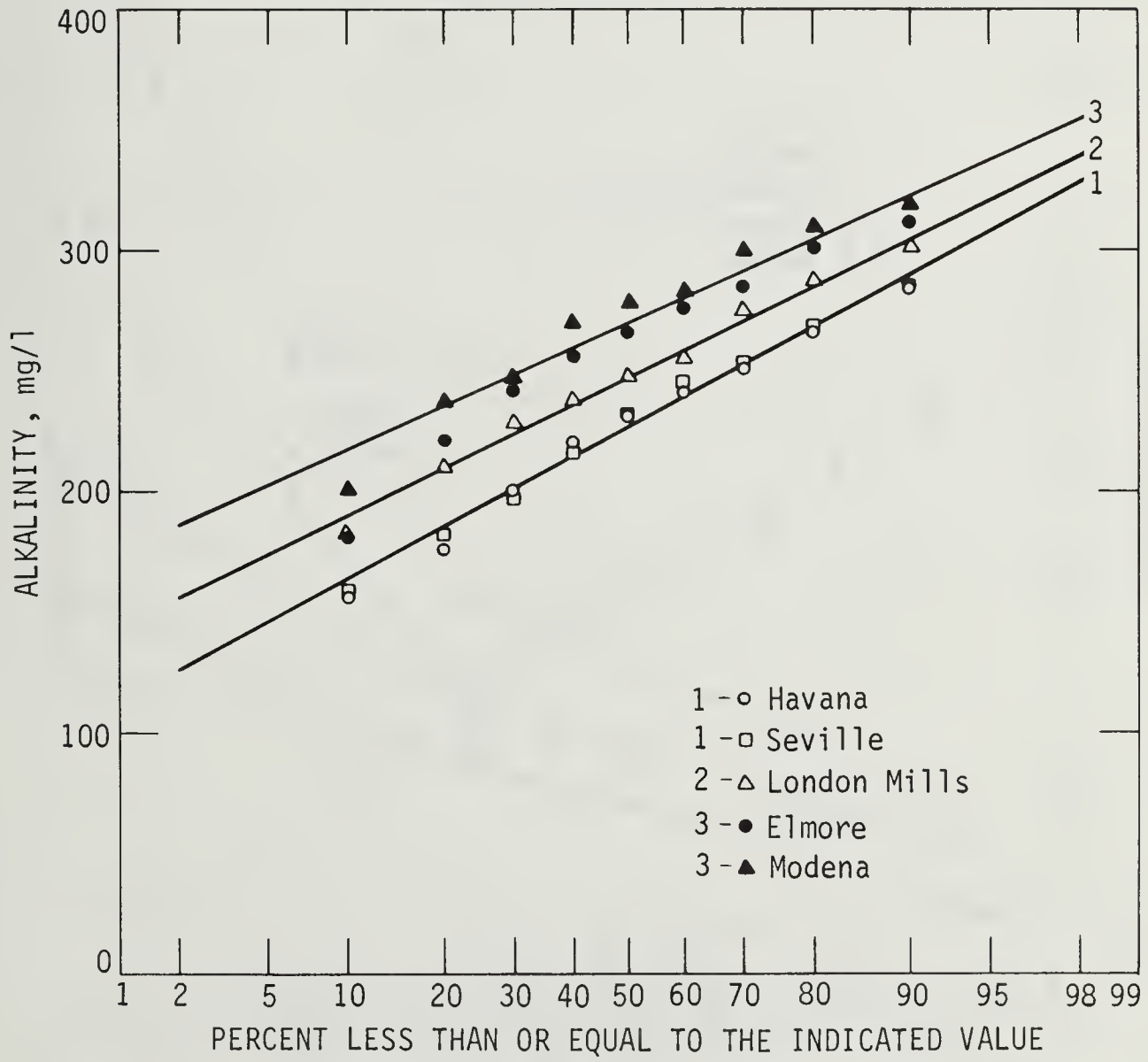

FIGURE 10.--Cumulative probability distribution of alkalinity.

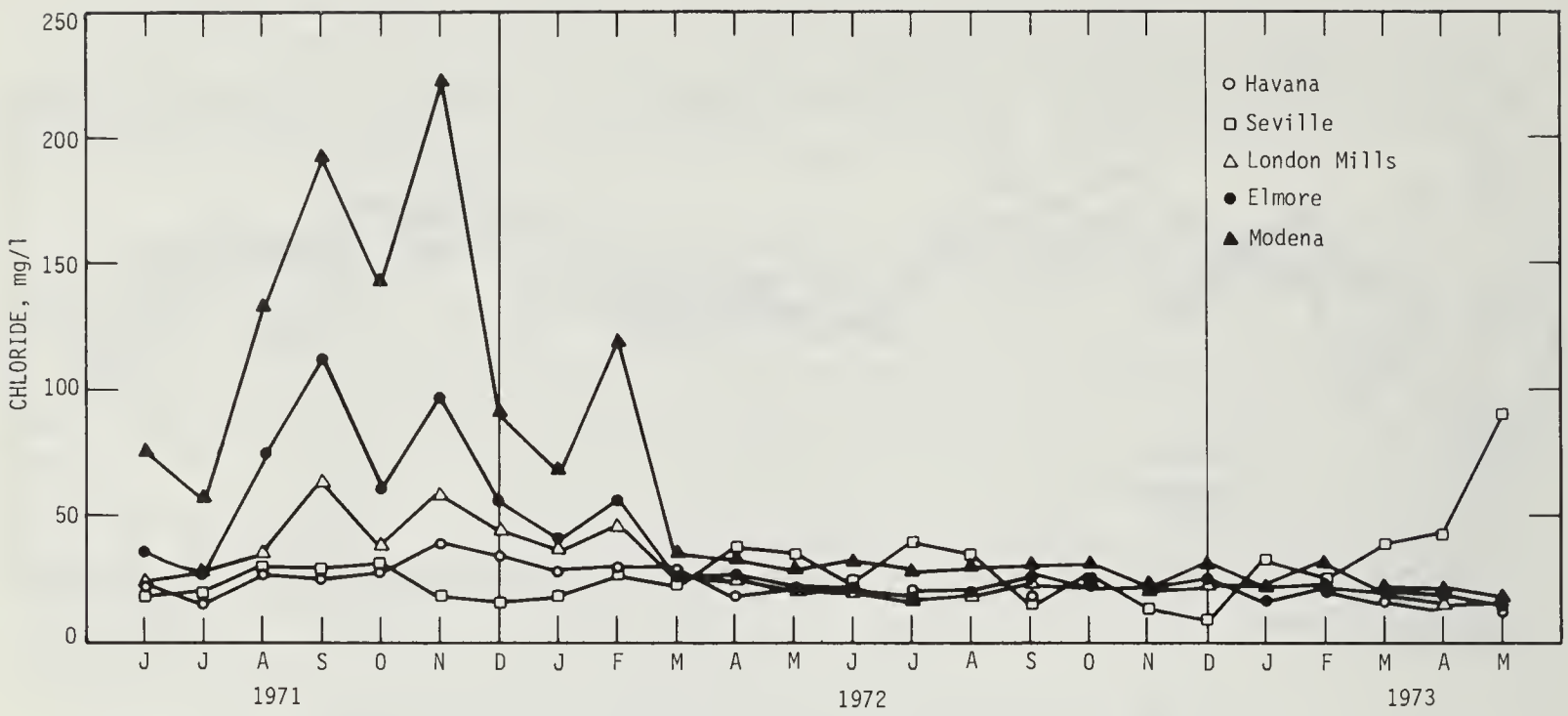

FIGURE 11.--Temporal variations of chloride.

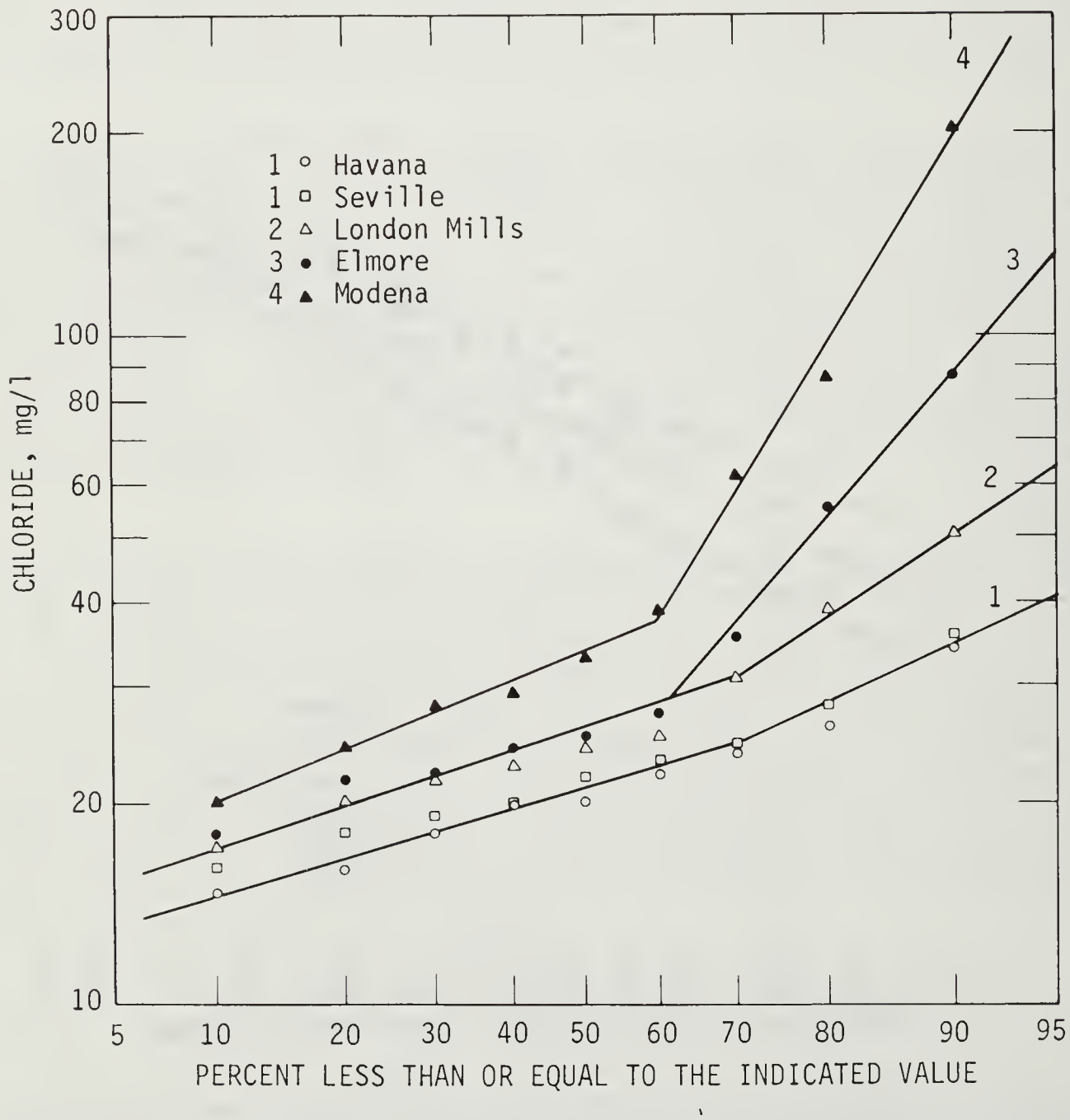

FIGURE 12.--Cumulative probability distribution of chloride.

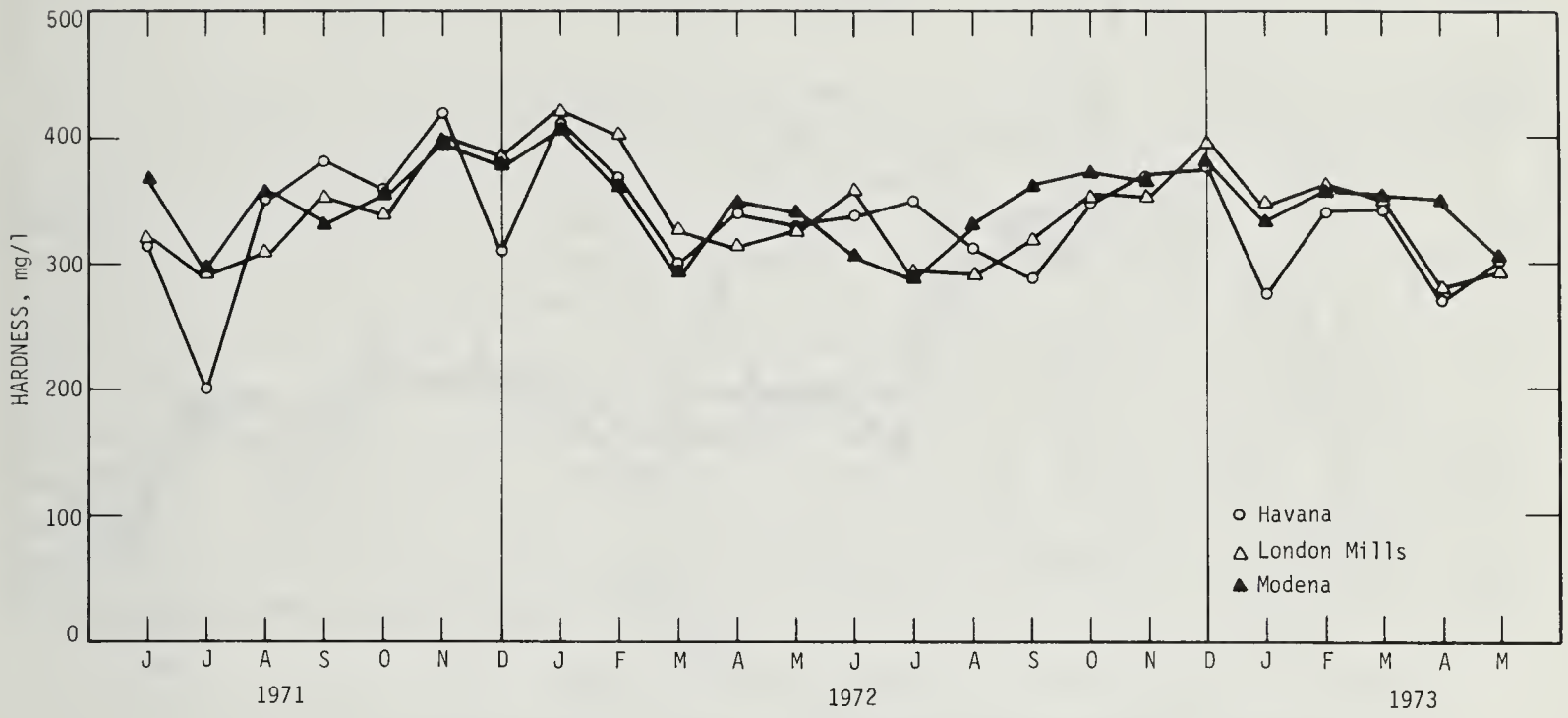

FIGURE 13.--Temporal variations of hardness.

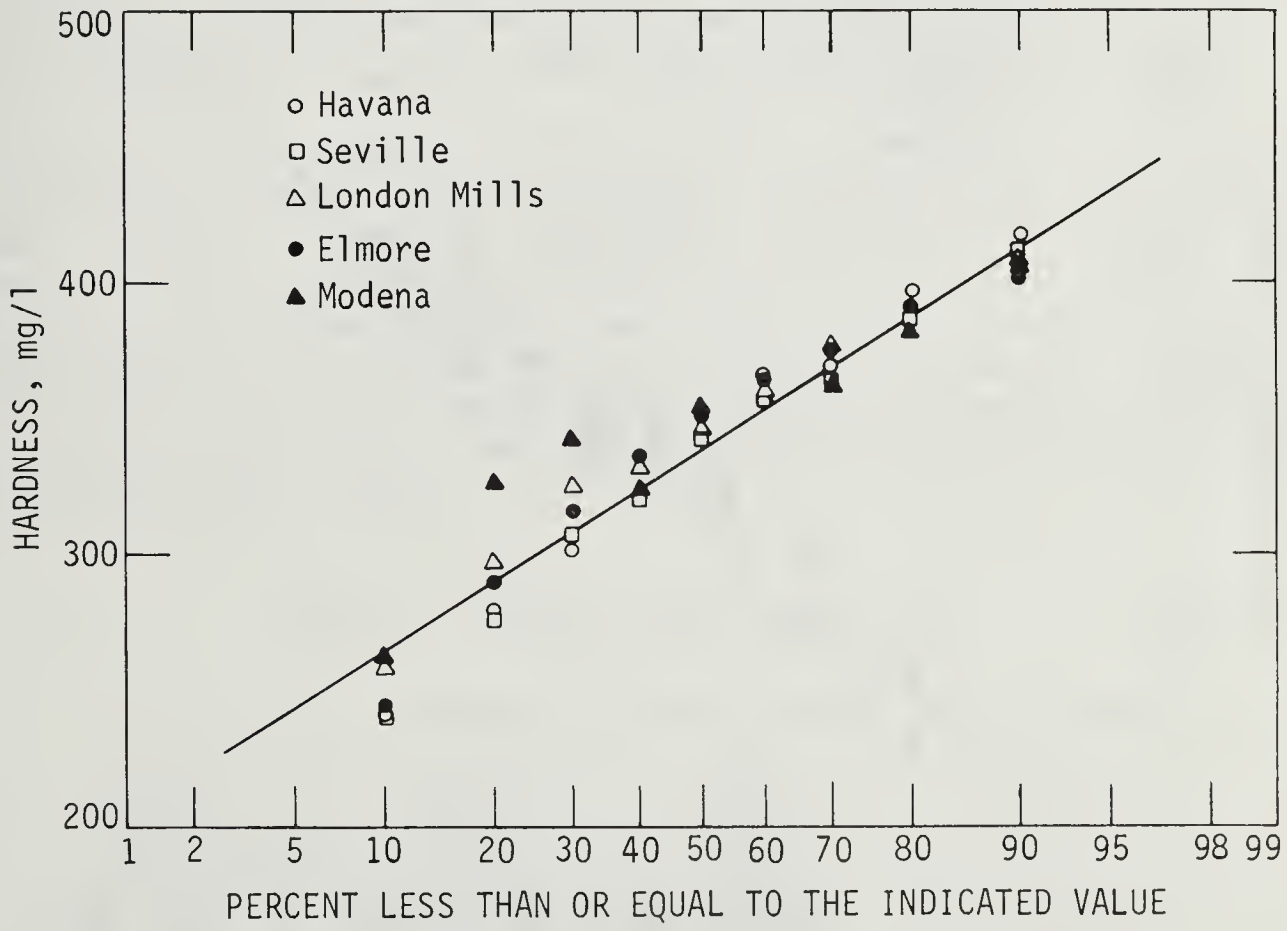

FIGURE 14.--Cumulative probability distribution of hardness.

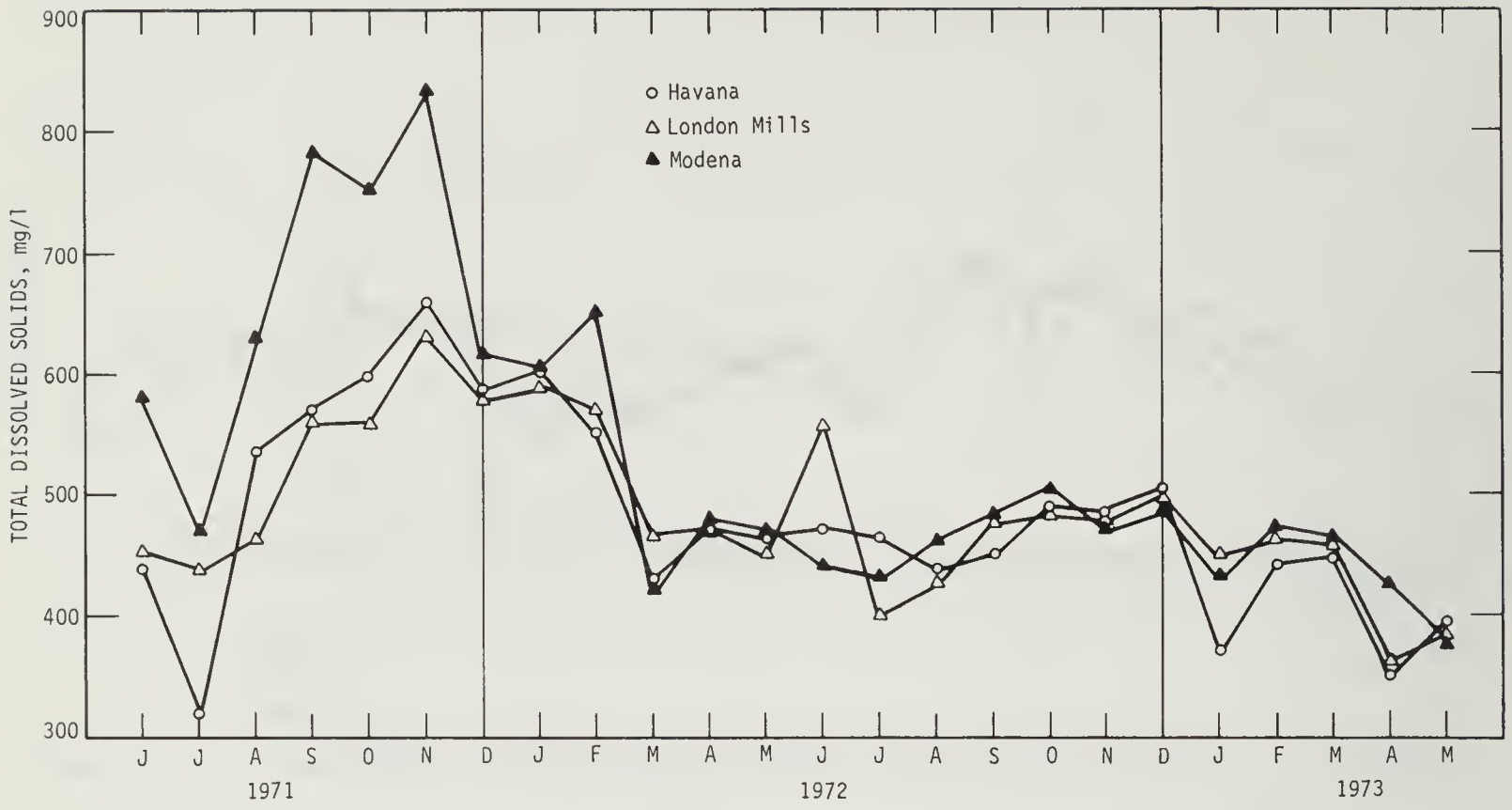

FIGURE 15.--Temporal variations of total dissolved solids.

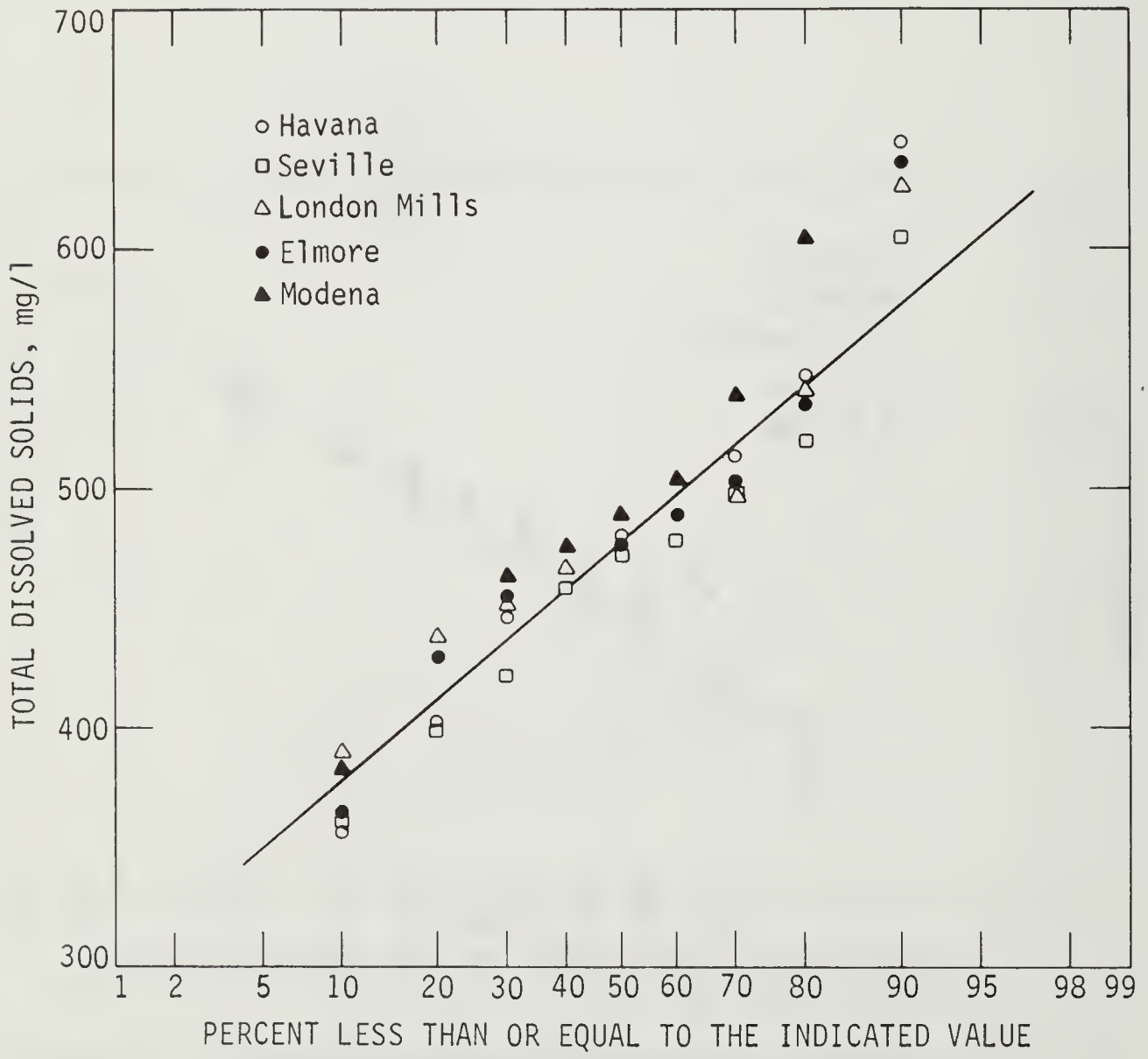

FIGURE 16.--Cumulative probability distribution of total dissolved solids.

considered sufficient to stimulate the nuisance algal blooms (Sawyer, 1974). The concern about algal growth stimulation has no significance in Illinois because the background count for Illinois surface waters is about 1 mg/l (Parker et al., 1974).

The spatial distributions of the mean values for nitrate and ammonium nitrogen are shown in Table 2. The mean ammonium ion concentrations at Elmore, London Mills, Seville, and Havana are comparable. However, the mean concentration at Modena is nearly threefold because of its proximity to the Kewanee municipal waste treatment plant. Even though the range of values for ammonium was 0 to 3.7 mg/l, about 20 percent of the observations were 0 in value, 70 percent of the observations were less than 0.1 mg/l, and only about 3 percent of the observations had values greater than 1.0 mg/l. The mean concentration of nitrogen is the highest at Modena, and it decreases progressively downstream. A similar phenomenon was observed in other Illinois streams. This is generally considered a dilution effect of the increased streamflow in the downstream direction (Evans and Wang, 1970).

Figure 17 shows the temporal variations of nitrate in the Spoon River at all five sampling locations. The spatial stratification of nitrate concentration in the river water is obvious, with the highest concentration prevailing for the uppermost sampling point at Modena, and the lowest value for Havana. This fact is reinforced by Figure 18 which shows the cumulative probability distribution of nitrate for all sampling locations. As nitrate-nitrogen concentration is generally found to be highly correlated with streamflow, the temporal variations in nitrate concentration should follow the variations in flow. Comparison of Figure 17 with Figures 2 and 3 shows that this is generally true.

If the streamflow and the concentration of a constituent are known, it is possible to compute the load factor transported by the stream at that point. Table 3 indicates the nitrate-nitrogen load transported by the stream at the five sampling locations. The nitrate-nitrogen contribution to the river from the watershed ranges from 16.5 pounds per acre per year (lbs/ac/yr) at Modena to 10.0 lbs/ac/yr at Havana. In comparison, the average contribution from the 1030-square-mile drainage area of the Kaskaskia River upstream of Shelbyville was about 21 lbs/ac/yr (Harmeson and Larson, 1970).

TABLE 3. Nitrate-Nitrogen Loads

Station	lbs/day	lbs/sq mi/day	lbs/ac/yr
Havana	31,571	17.5	10.0
Seville	33,922	21.2	12.1
London Mills	24,098	22.5	12.8
Elmore	16,058	28.2	16.1
Modena	4,453	28.0	16.5

Chemical Oxygen Demand. Erosion can be a major contributor of organics and nutrients to surface waters. Organic matter will be among the

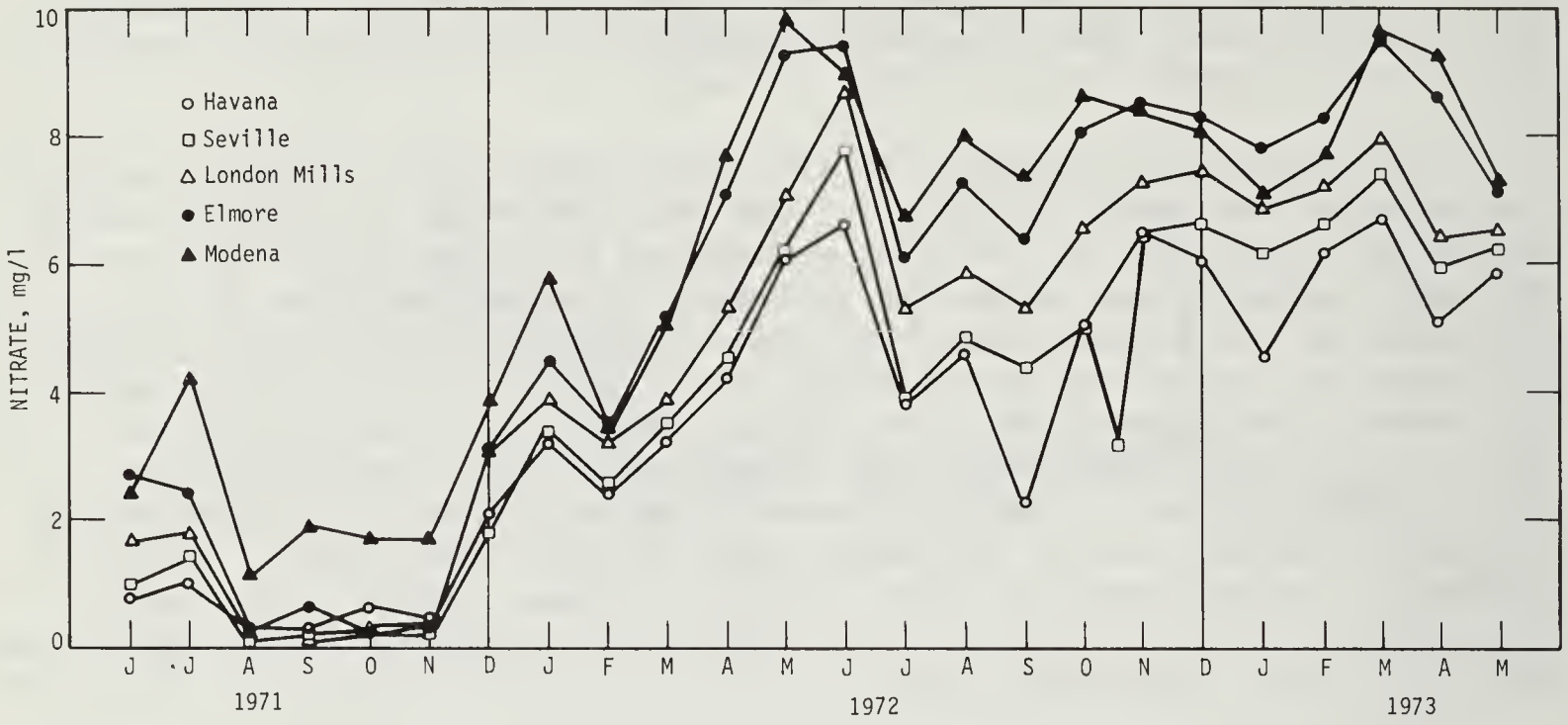

FIGURE 17.--Temporal variations of nitrate.

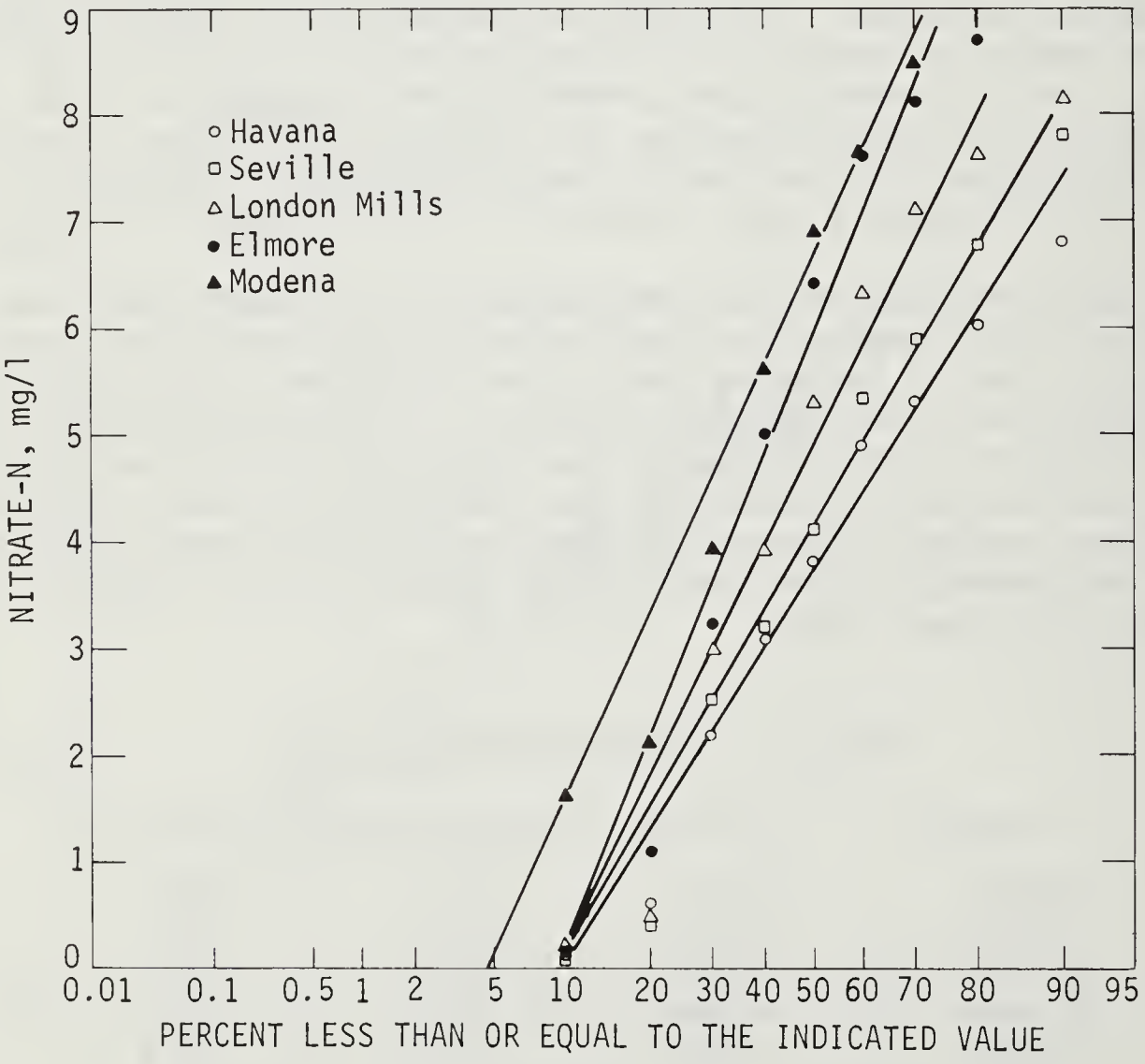

FIGURE 18.--Cumulative probability distribution of nitrate.

first constituents to be moved by runoff because of its low density and high concentration in surface soils. The mean values for chemical oxygen demand (COD) for Spoon River water samples varied from 23.7 to 32.3 mg/l as shown in Table 2. Figure 19 shows a plot of the monthly mean values of COD for three sampling locations. Figure 20, showing the probability distribution of COD values for all the sampling stations, indicates that these values are log-normally distributed and that they belong to the same statistical population.

SUMMARY

The physical and chemical water quality characteristics of the Spoon River for the 2 years from June 1971 through May 1973 are summarized. The river water temperature exhibits distinct annual cyclic fluctuations. The dissolved oxygen concentration shows a remarkable degree of inverse relationship to water temperatures because the oxygen resources of the river are not stressed to any significant degree by oxygen demanding organic matter. The turbidity is generally very high except during periods of very low streamflow.

The Spoon River, typical of midwestern waters, is rich in alkalinity and hardness. The nitrate concentration in the Spoon River was highest at Modena, near the headwaters, and decreased progressively downstream. A similar phenomenon was also observed in other Illinois streams. The nitrate-nitrogen concentrations in the Spoon River at Havana and Seville met the IPCB's standard of 10 mg/l as nitrogen at all times, whereas the limit was exceeded at the other three sampling locations about 5 percent of the time. The nitrate-nitrogen contribution to the river from the watershed ranged from 16.5 lbs/ac/yr at Modena to 10.0 lbs/ac/yr at Havana.

ACKNOWLEDGMENTS

Several members of the staff of the Water Quality Section of the Illinois State Water Survey participated in this study. The authors express their appreciation to Jack Williams, Jr., for collecting the weekly samples and to William T. Sullivan, Daniel J. Brabec, and David L. Hullinger for performing various chemical analyses. John Brother, Jr., prepared the illustrations. Dr. James C. Neill performed the statistical analyses.

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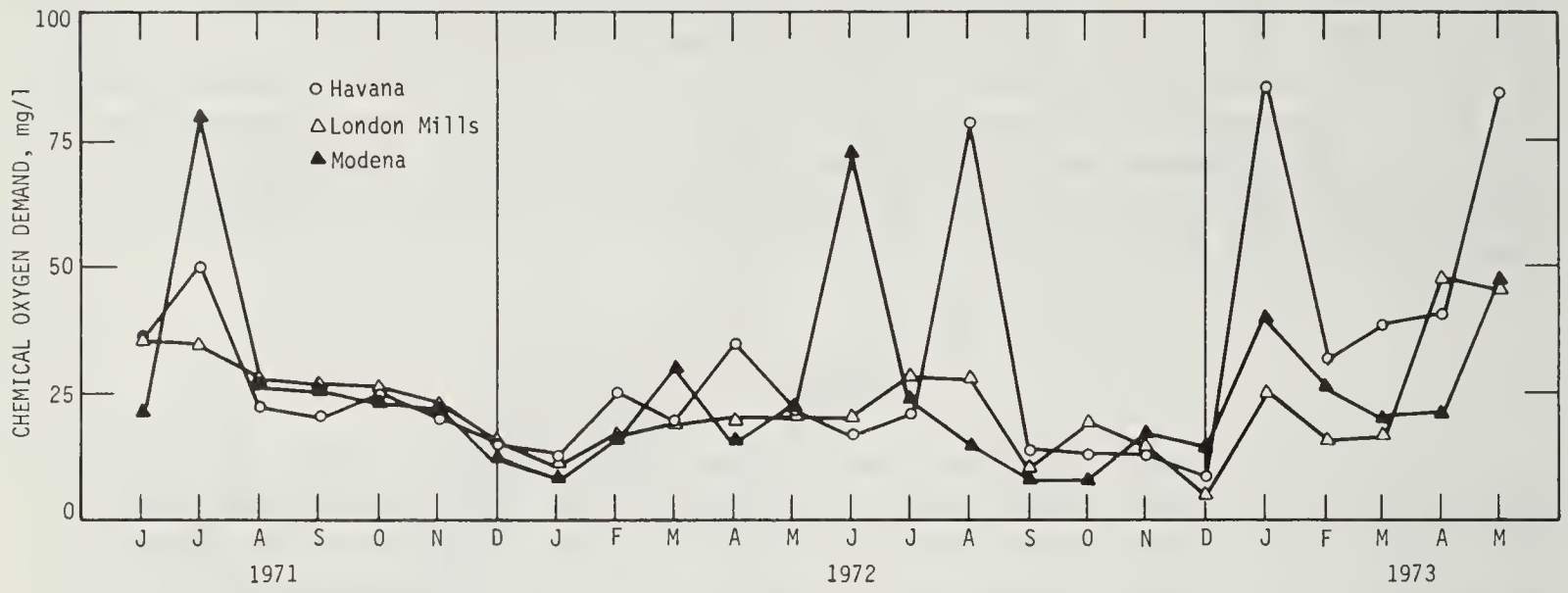

FIGURE 19.--Temporal variations of chemical oxygen demand.

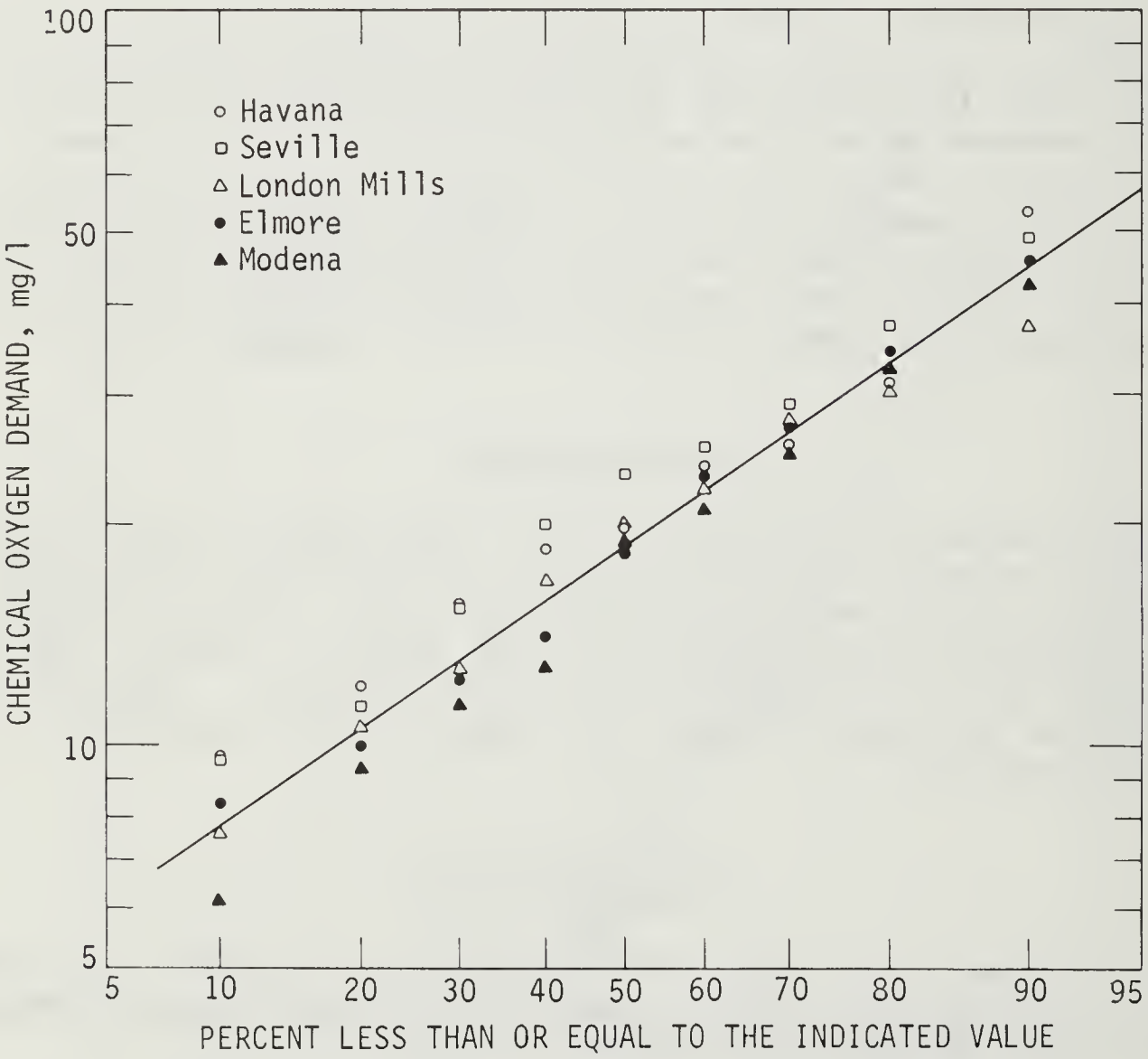

FIGURE 20.--Cumulative probability distribution of chemical oxygen demand.

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AN ASSESSMENT OF WATER QUALITY IN THE SPOON RIVER, PART 2

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ABSTRACT

The spatial and temporal variations of calcium, magnesium, manganese, iron, silica, sulfate, and phosphorus at five locations on the Spoon River are reported here. Stream gaging data at the sampling sites and synthesized flow data, where flow measurements were lacking, were used to calculate the nutrient loads transported by the river. Results of the 2-year study show: 1) the spatial distribution of calcium and magnesium differs very little along the river; 2) sulfate concentrations tend to increase in the downstream direction; 3) total iron concentrations exceed the Illinois Pollution Control Board limit of 1 mg/l 90 percent of the time; 4) concentrations of silica ranged from 9.36 mg/l at Modena to 7 mg/l at Havana; 5) phosphorus concentrations exceed the state standards 100 percent of the time at Modena and about 90 percent of the time at London Mills, Seville, and Havana.

INTRODUCTION

Part 2 of the Spoon River water quality report presents the weekly phosphorus data and the chemical quality characteristics observed on a once every three weeks basis. The seasonal variations in these water quality characteristics are also examined. The physical descriptions of the study area are given in Part 1.

WATER QUALITY

Individual chemical determinations for the samples were analyzed by procedures outlined in Table 1. Results of determinations are expressed as milligrams per liter (mg/l) for all the parameters. Results of analysis for means and ranges for water quality parameters considered in this report and for streamflows are shown in Table 2. An attempt was made to delineate the seasonal changes in the values. The data were classified into biannual, triannual, and quadriannual groupings, and the central tendencies of the parameters were evaluated. No periodic fluctuations could be discerned in any of the water quality parameters. Because data

TABLE 1. Anayltical Procedures

Determinations	Analytical procedures
Calcium	EDTA titrimetric method
Magnesium	Calculation
Sulfate	Gravimetric method with drying of residue
Manganese	Persulfate method
Silica	Molybdosilicate method
Iron (filterable)	0.45μ membrane filtered, phenanthroline method
Iron (particulate)	Total iron by phenanthroline-iron (filterable)
Total Dissolved Phosphorus-P	0.45μ membrane filtered persulfate oxidation and ascorbic acid reduction to molybdate blue
Dissolved Orthophosphate-P	0.45μ membrane filtered, ascorbic acid reduction to molybdate blue
Dissolved Inorganic Phosphate-P	0.45μ membrane filtered, $Bi(NO_3)_3$ hydrolysis, ascorbic acid reduction to molybdate blue

for the Spoon River are for only 2 years, long-term fluctuations in the parametric values, if any, could not be detected.

Calcium and Magnesium. Calcium salts and calcium ions are among the most commonly encountered substances in midwestern water. The Illinois Pollution Control Board (IPCB) does not stipulate any limit for the concentration of calcium.

The temporal variations of calcium at three sampling stations, Modena, London Mills, and Havana, are shown in Figure 1. These represent the quality characteristics of the river at the beginning, intermediate, and final reaches of the river. The concentration of calcium tends to vary at these locations in unison. The means and ranges of values for calcium at all five sampling locations appear to be similar in magnitude (Table 2). Even though the Modena sampling station is closest to the

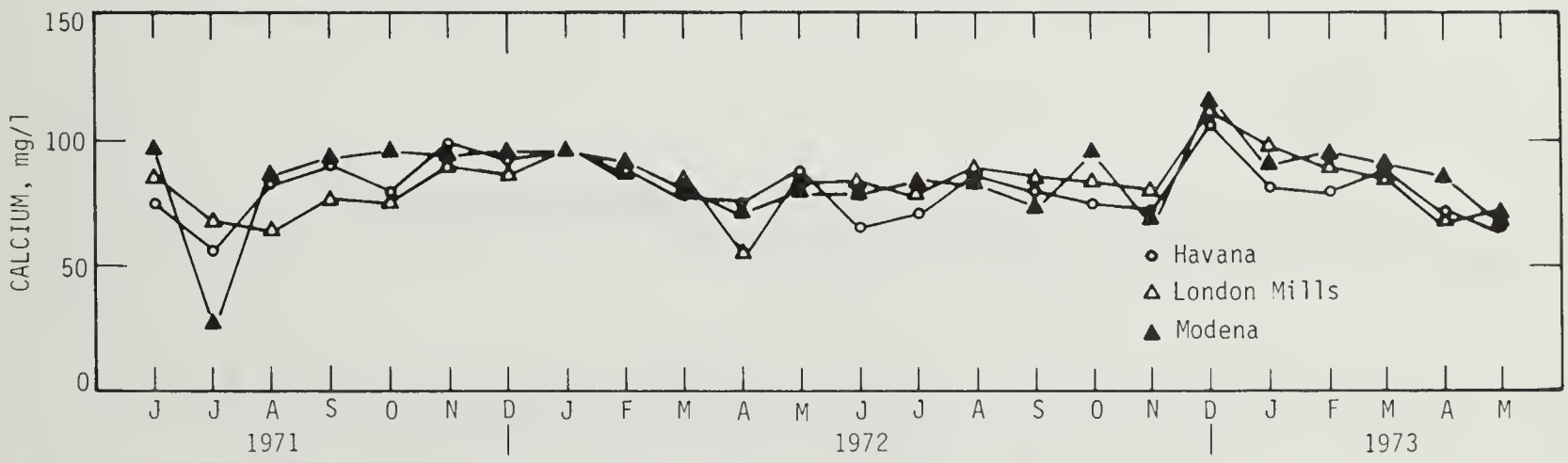

FIGURE 1.--Temporal and spatial variations in calcium.

TABLE 2. Observed Mean and Range of Concentrations in Spoon River (mg/l)

Parameter	Havana Mean	Havana Range	Seville Mean	Seville Range	London Mills Mean	London Mills Range
Calcium	82.0	54.0-110.0	80.0	45.0-114.0	83.0	47.0-113.0
Magnesium	31.0	18.0-46.0	31.0	19.0-47.0	31.0	11.0-45.0
Sulfate	126.9	22.2-239.6	118.9	53.9-339.0	100.5	58.4-164.4
Manganese	0.24	0.01-2.9	0.25	0.01-1.91	0.19	0.0-0.82
Iron (filterable)	0.25	0.01-1.77	0.26	0.0-2.52	0.19	0.01-0.66
Iron (particulate)	10.21	0.37-129.97	15.68	0.22-163.97	9.54	0.38-71.04
Silica	6.95	0.50-11.30	7.09	0.38-11.98	7.33	0.27-13.51
Total Dissolved Phosphorus-P	0.13	0.02-0.42	0.12	0.03-0.36	0.14	0.03-0.86
Dissolved Ortho-PO_4-P	0.08	0.00-0.26	0.06	0.0-0.22	0.07	0.0-0.68
Dissolved Inorganic PO_4-P	0.09	0.00-0.33	0.08	0.0-0.27	0.09	0.0-0.74
Flow (cfs)	1286	32-15,700	1187	28-15,500	759	18-9,000

Parameter	Elmore Mean	Elmore Range	Modena Mean	Modena Range
Calcium	83.0	29.0-118.0	84.0	27.0-118.0
Magnesium	29.0	11.0-50.0	33.0	8.0-42.0
Sulfate	82.7	25.9-131.0	83.6	20.6-176.9
Manganese	0.18	0.0-1.40	0.20	0.0-0.87
Iron (filterable)	0.21	0.0-0.64	0.26	0.0-3.8
Iron (particulate)	9.63	0.37-84.78	11.11	0.71-175.2
Silica	8.13	0.11-13.38	9.36	2.27-15.97
Total Dissolved Phosphorus-P	0.20	0.02-0.68	0.47	0.11-2.68
Dissolved Ortho-PO_4-P	0.13	0.01-0.53	0.38	0.02-2.32
Dissolved Inorganic PO_4-P	0.15	0.01-0.58	0.41	0.05-2.40
Flow (cfs)	410	9-4,718	108	2-1,248

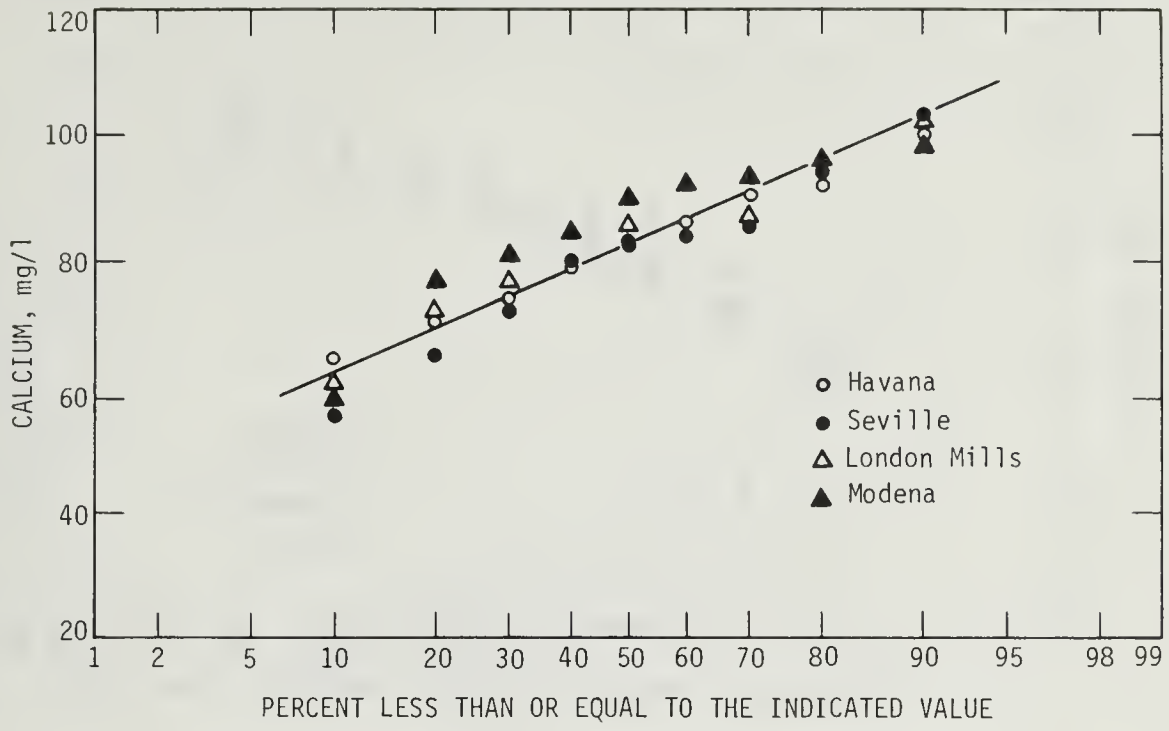

FIGURE 2.--Cumulative probability distribution of calcium.

Kewanee waste treatment plant, calcium concentrations at this site are no different from the rest. The contribution of calcium salts to the river from natural sources is more dominant than the contribution from the municipal source. Figure 2 again confirms that there is very little difference in the spatial distribution of calcium along the river.

Magnesium also ranks among the most common elements, constituting about 2.1 percent of the earth's crust. There is no standard set for magnesium in surface waters in Illinois.

The concentrations of magnesium in the Spoon River ranged from 8 to 50 mg/1. As in the case of calcium, magnesium concentrations at all five sampling locations varied in unison and the average values and the range of values at each of these locations were comparable (Table 2). Figures 3 and 4 also indicate that there is no spatial variation in magnesium concentrations along the river.

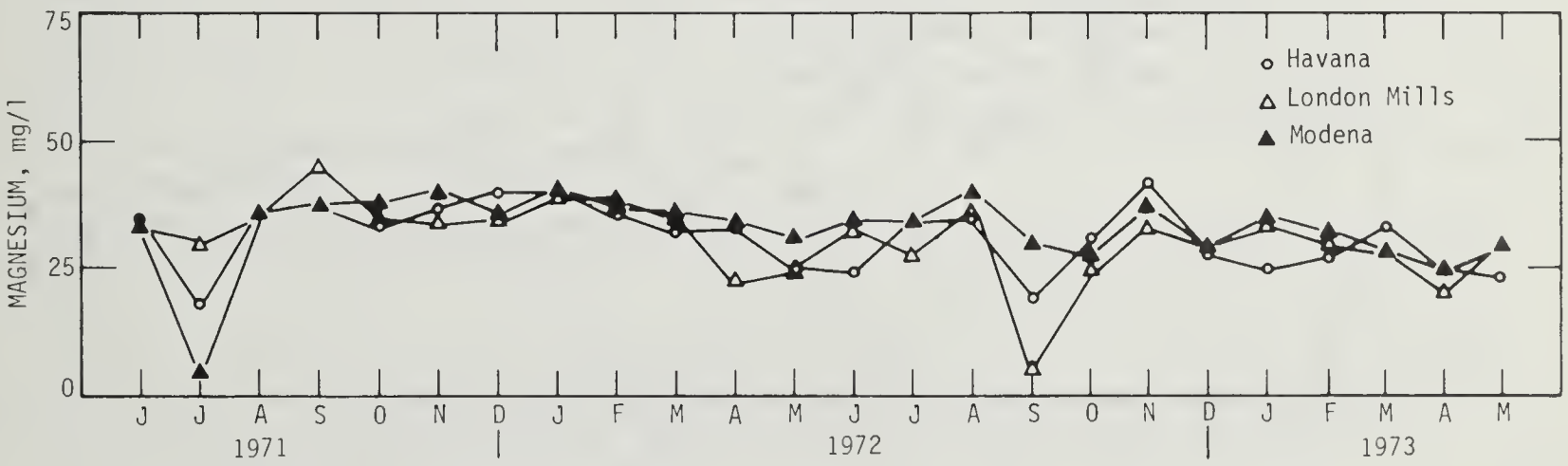

FIGURE 3.--Temporal and spatial variations in magnesium.

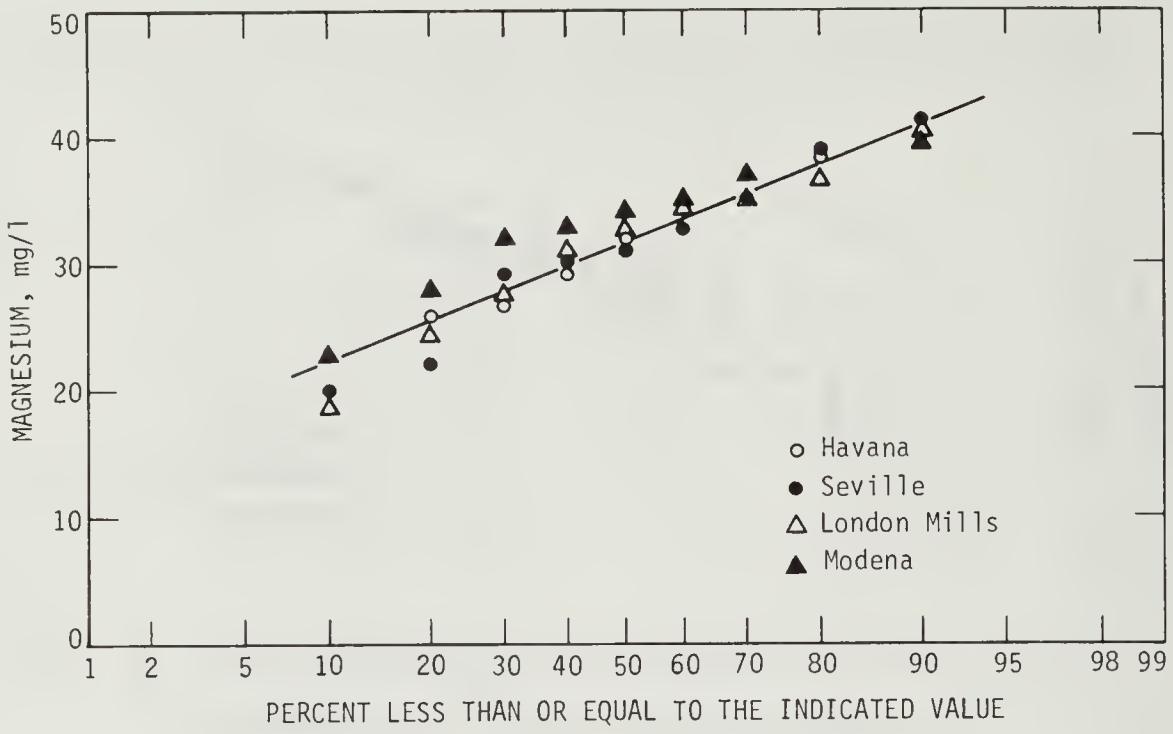

FIGURE 4.--Cumulative probability distribution of magnesium.

Sulfate. The recommended sulfate concentration in potable supplies is limited to 250 mg/l (American Public Health Association, 1971). The IPCB has stipulated a limit of 500 mg/l for sulfate in surface waters in Illinois.

The mean values of sulfate concentrations given in Table 2 show a general trend of increasing concentration in the downstream direction of the river. Such a trend is also apparent in most of the individual observations. The spatial segregation of sulfate concentration values are borne out clearly by Figures 5 and 6. Sulfate concentrations at Modena do not seem to be influenced by the Kewanee waste treatment plant discharges.

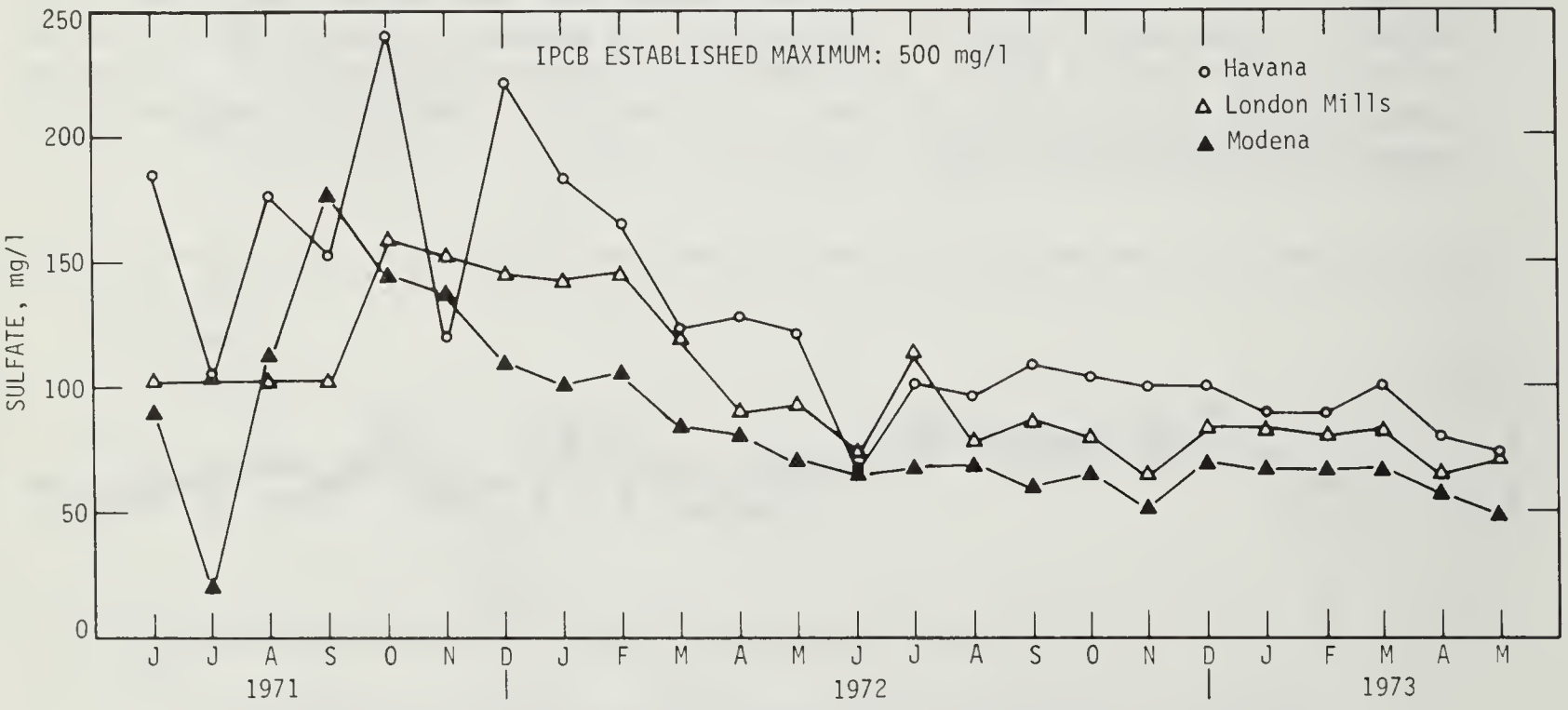

FIGURE 5.--Temporal and spatial variations in sulfate.

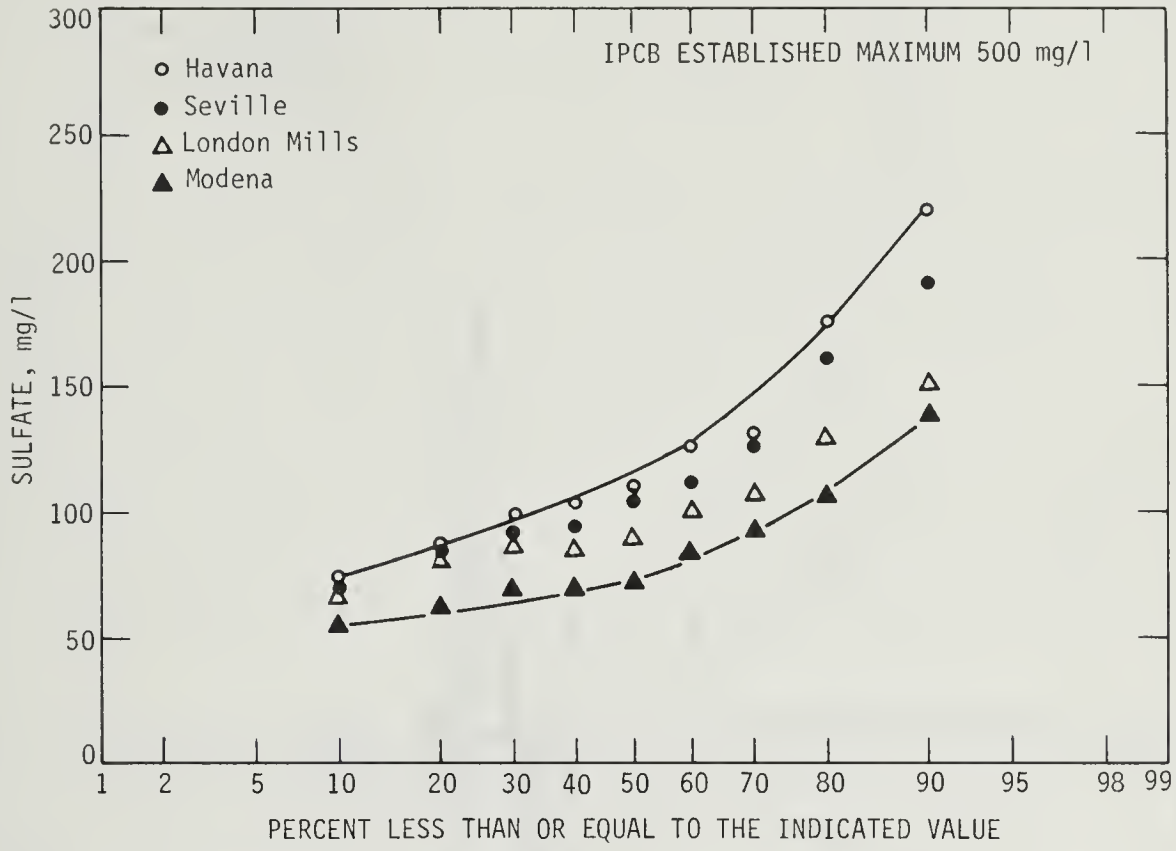

FIGURE 6.--Cumulative probability distribution of sulfate.

Iron and Manganese. Iron ranks next to aluminum in the abundance of metals in the earth's mantle, though natural waters contain variable but minor amounts of iron.

Generally accepted standards for iron in surface water supply sources is 0.3 mg/l or less. The limit is based on aesthetic and taste considerations instead of physiological reasons. Drinking water containing iron in unpalatable concentrations of say about 1.0 mg/l would have little effect on the total daily intake, as most diets contain 7 to 35 mg per day (McKee and Wolf, 1963). The IPCB limits the concentrations of iron in streams to 1.0 mg/l.

The limits for manganese in public water supplies also are set for aesthetic and economic reasons rather than for physiological reasons. Manganese in potable water cannot be considered a physiological hazard because the normal dietary intake is far higher than the amount that would be tolerated aesthetically in drinking water. The IPCB has stipulated a limit of 1.0 mg/l in streams and 0.05 mg/l in public and food processing water supplies.

The temporal variations of total iron at four of the five sampling stations are shown in Figure 7. The peaks and valleys of these plots follow the general trend of the river flow (shown in Figures 2 and 3 of Part 1). About 96 to 98 percent of the total iron is in the particulate form. As the sediment load in the stream increases with increasing streamflow, unfilterable iron associated with river sediment also increases with flow.

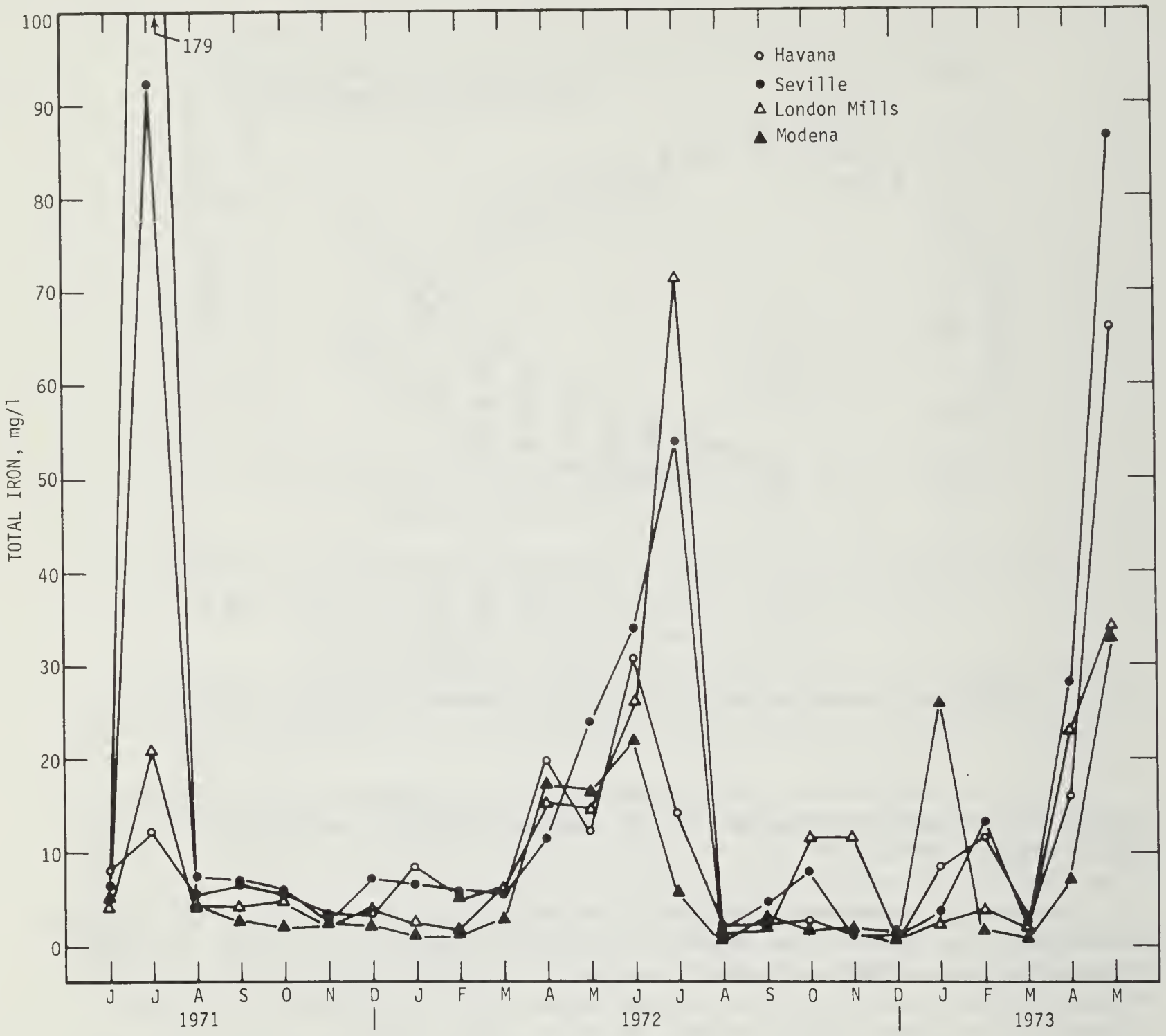

FIGURE 7.--Temporal and spatial variations in total iron.

Though there is no clear cut spatial trend in the occurrence of iron in the Spoon River, iron concentrations at Seville generally exhibit the highest values. Even though Havana is located downstream of the Seville sampling station, the iron concentration is lower at Havana than at Seville. This is mainly because of the partial settling of the suspended sediments near Havana caused by the backwater effect of the confluence of the Spoon River with the Illinois River.

Figure 8 shows the cumulative probability distribution of total iron at four sampling stations. The data for Elmore lie within the envelopes drawn for the Seville and Modena stations. At all the stations, total iron concentrations exceeded the IPCB limit of 1 mg/l for 90 percent of the time. Also, except for very high concentrations which occurred only 10 percent of the time, concentrations at Modena were the lowest.

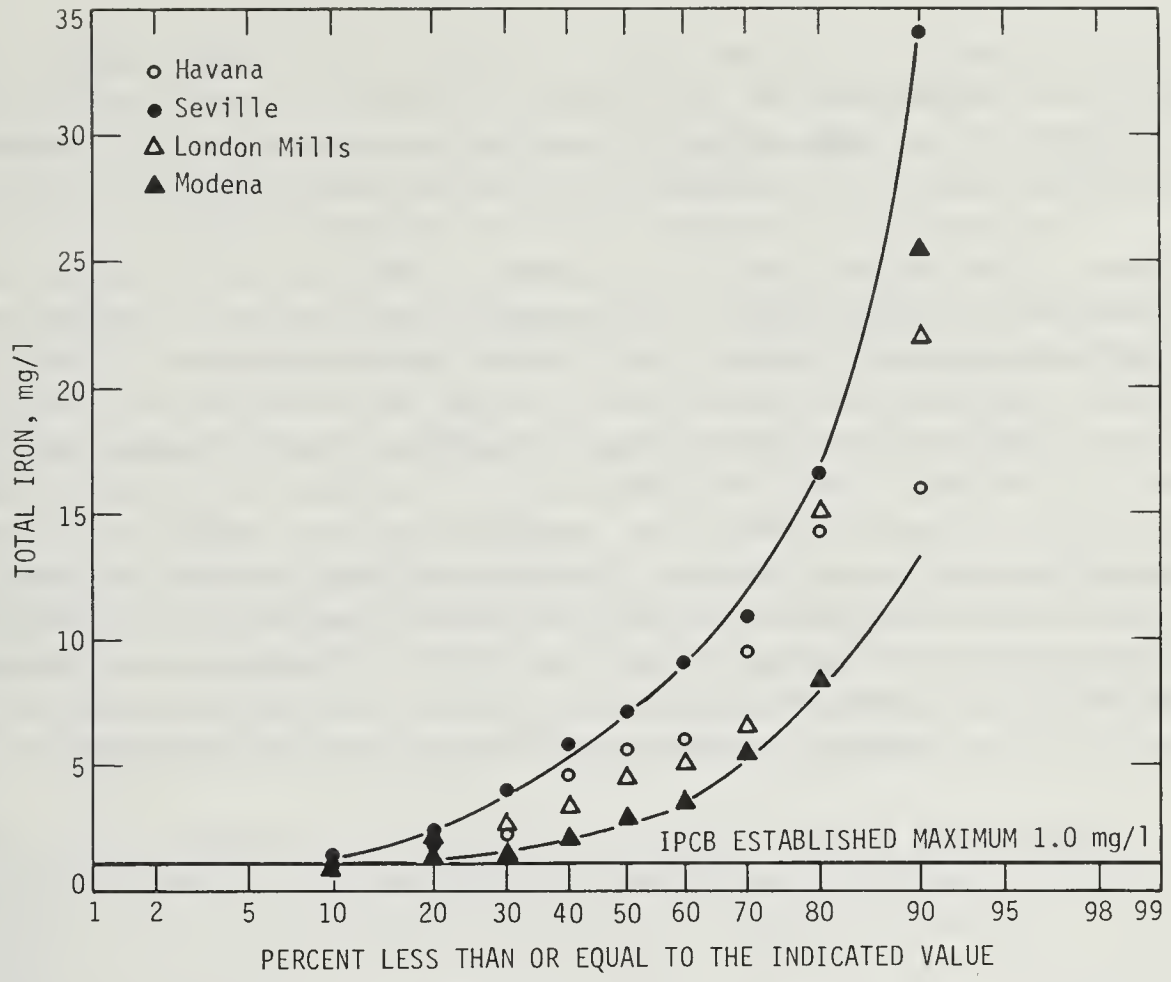

FIGURE 8.--Cumulative probability distribution of total iron.

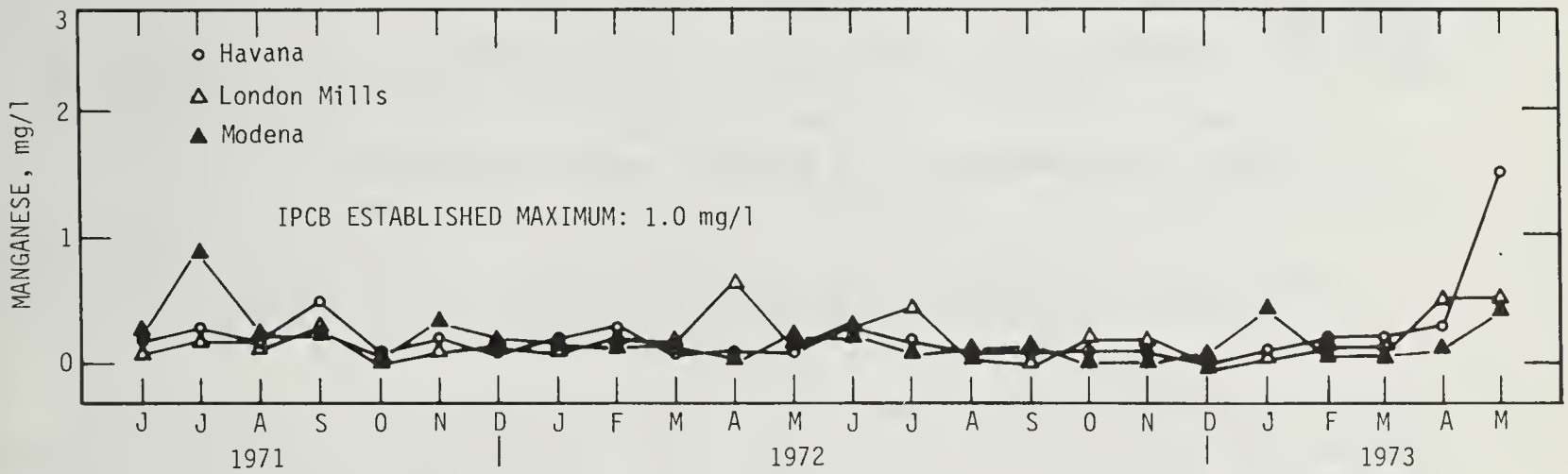

FIGURE 9.--Temporal and spatial variations in manganese.

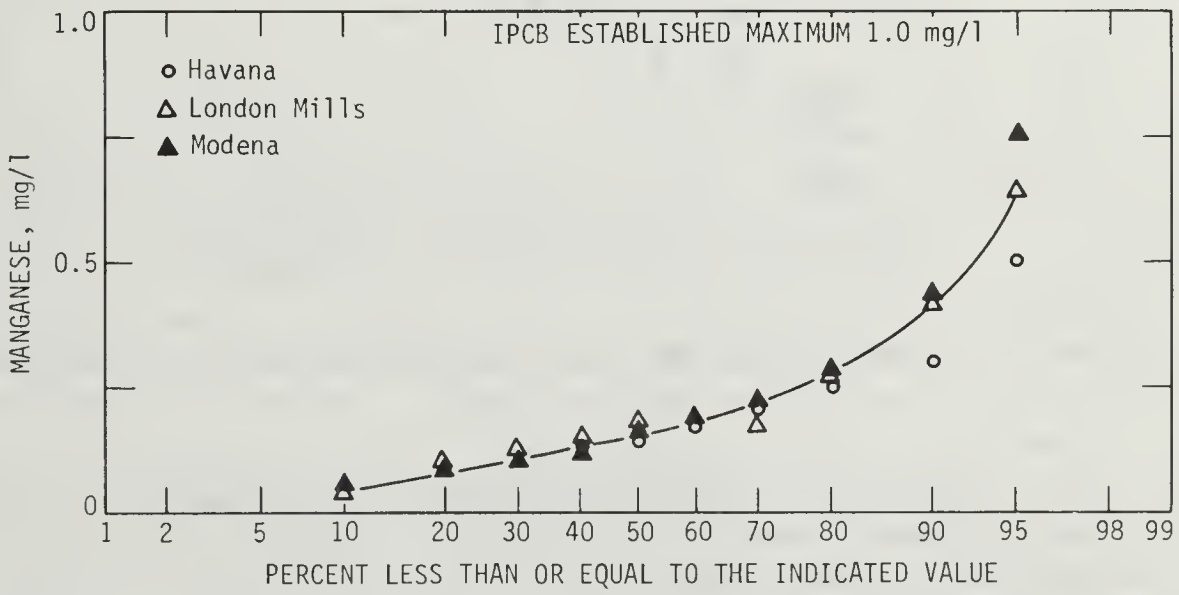

FIGURE 10.--Cumulative probability distribution of manganese.

Figures 9 and 10 indicate that, except for a few extreme values, manganese concentrations in the river are well within the stipulated limits. There is no significant spatial variation in the occurrence of manganese along the river except for a very few extreme values.

Silica. Concentrations of silica in the Spoon River do not appear to be excessive, being within the range cited in the literature (American Public Health Association, 1971) for surface waters. The average silica concentration for the entire period of observation at Havana, Seville, and London Mills was 7 mg/l, whereas the average concentrations at Elmore and Modena were, respectively, 8.13 and 9.36 mg/l (Table 2 and Figure 11). Evans (1968), in considering the addition of common ions from domestic use of water, documented that there is nearly a two- to three-fold increase in silica concentration in municipal waste waters compared with the tap waters in their respective locations. The elevated silica concentrations at Modena and Elmore are obviously influenced by the Kewanee waste treatment plant discharges.

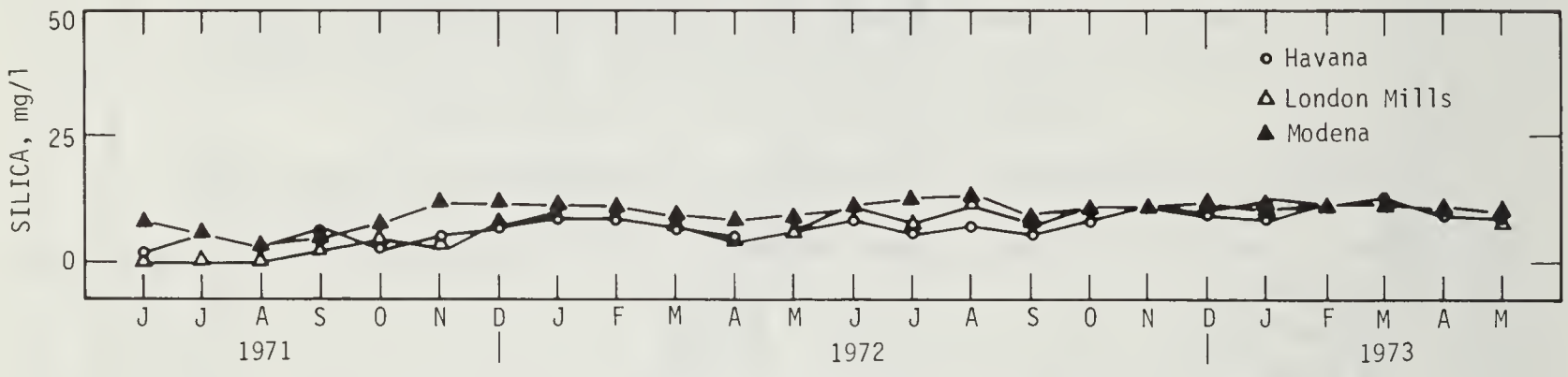

FIGURE 11.--Temporal and spatial variations in silica.

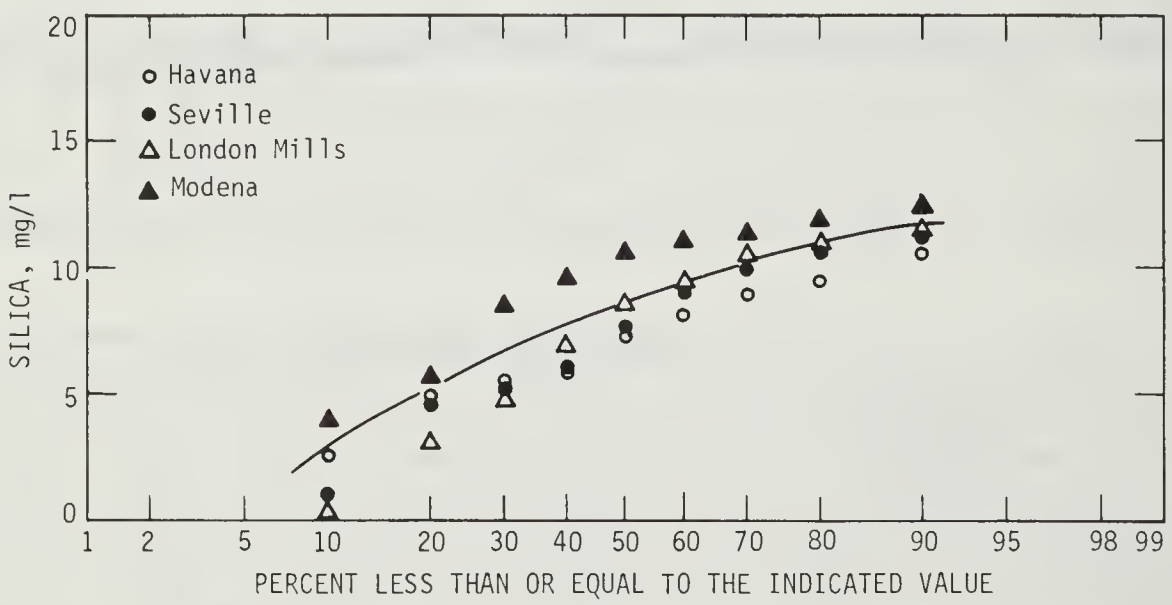

FIGURE 12.--Cumulative probability distribution of silica.

From Figure 12, it is apparent that data for Modena belong to one statistical population, whereas the data for the other three stations are from a different population.

Phosphate-Phosphorus. Because phosphorus is essential to the plant growth processes, it has become the focus of attention in the entire eutrophication issue. With phosphorus being singled out as the most probable limiting nutrient and the one most easily controlled by removal techniques, various facets of phosphorus chemistry and biology have been extensively studied in natural environments. To prevent biological nuisances, Illinois Environmental Protection Agency stipulates "Phosphorus as P shall not exceed .05 mg/l in any reservoir or lake, or in any stream at the point where it enters any reservoir or lake."

In any river system, the two aspects of interest for phosphorus dynamics are the phosphorus concentration, and the phosphorus flux (concentration times flow rate) as functions of time and distance. The concentration itself indicates the possible limitations that this nutrient can place on vegetative growth in the stream and the phosphorus flux is a measure of phosphorus nutrient input and output rates.

The means and ranges of values of total dissolved phosphorus, dissolved orthophosphate, and dissolved inorganic phosphate for the Spoon River at all five sampling stations are shown in Table 2. The mean total dissolved phosphorus concentration and the mean orthophosphate concentration are the highest at Modena and the mean values for these parameters level off from the London Mills station downstream. The proximity of the Kewanee waste treatment plant discharge is the principal reason for the high phosphorus values at Modena. The average of the ratios of individual observations for dissolved orthophosphorus and total dissolved phosphorus was the highest at Modena. The values were 0.73, 0.60, 0.47, 0.45, and 0.50, respectively, for the sampling points at Modena, Elmore, London Mills, Seville, and Havana. The dissolved organic phosphorus, obtainable as a difference in value between the total dissolved phosphorus and dissolved inorganic phosphorus, had values varying from 0.06 mg/l at Modena to 0.04 mg/l at Havana.

The temporal variations of total dissolved orthophosphate at three sampling stations are shown in Figure 13. The phosphorus concentrations at Havana and London Mills are very nearly the same, as were the concentrations at Seville which are not plotted. Phosphorus concentrations were the highest at Modena, and concentrations at Elmore were intermediate between those at Modena and those at London Mills.

The spatial variations of total dissolved phosphorus fit the 'dilution effect' theory postulated by Wang and Evans (1970) in the Spoon River segment from its headwaters down to London Mills. From there on, the total dissolved phosphorus concentration had a steady value unaffected by the magnitudes of streamflow. During the first year of sampling, the rainfall and runoff were scarcer than the long-term normal values. Figure 13 reveals the dominant effect of the Kewanee waste treatment plant discharges during this period. However, during the second year of observations, when the runoff was well above normal values, phosphorus concentration levels at Modena were attenuated quite significantly.

The cumulative probability distribution of total dissolved phosphorus shown in Figure 14 further clarifies the earlier remarks about the spatial

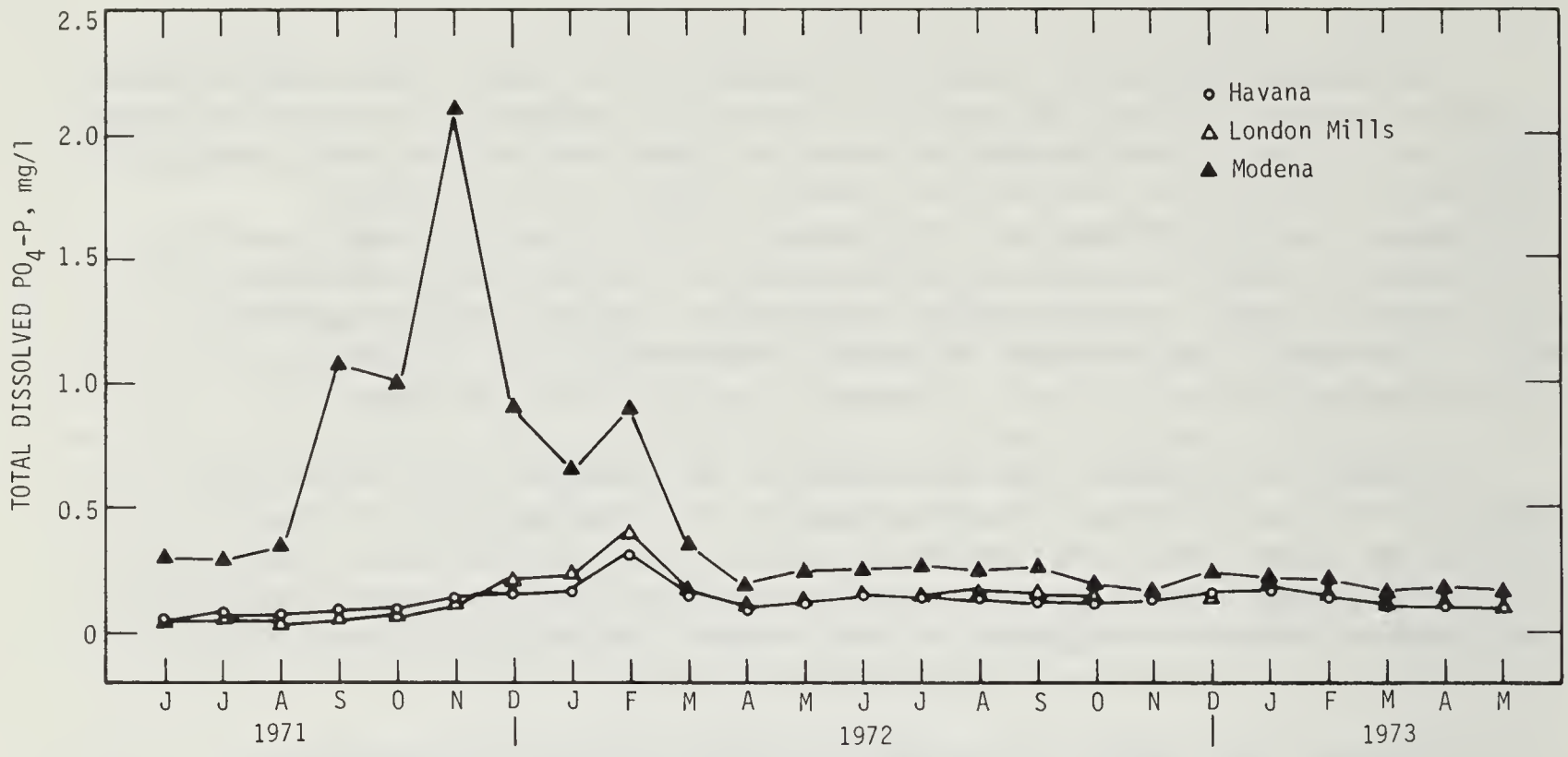

FIGURE 13.--Temporal and spatial variations in total dissolved phosphorus-P.

variations of phosphorus concentration. The phosphorus concentration values at Modena were in violation of the state's standards at all times and about 90 percent of the time at the last three downstream stations.

Table 3 shows the flux in pounds per day of phosphorus, manganese, iron, and silica in the Spoon River at all of the sampling locations. The mean total dissolved phosphorus loads varied from 820 lbs/day at Havana to 126 lbs/day at Modena. The phosphorus unit loads, expressed as pounds per acre per year, at Havana, Seville, London Mills, Elmore, and Modena were, respectively, 0.26, 0.27, 0.29, 0.36, and 0.47. The unit load for total PO_4-P estimated for the Kaskaskia River at Shelbyville was 0.17 lbs/ac/yr (Engelbrecht and Morgan, 1959).

TABLE 3. Flux of Some Micro-Nutrients in Spoon River (pounds/day)

Stations	Silica			Iron (total)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Havana	450	340571	46550	610	4069405	152999
Seville	98	314919	44758	353	5113364	211335
London Mills	35	200668	42534	185	1161123	68973
Elmore	10	113705	17777	96	591484	36973
Modena	37	33512	5406	31	109396	7473
	Total Dissolved Phosphorus			Manganese		
Havana	11	6775	820	19	90779	3223
Seville	6	4738	758	34	59551	2878
London Mills	5	3334	538	8	15481	1164
Elmore	3	3818	357	4	9742	585
Modena	5	890	126	1	1386	100

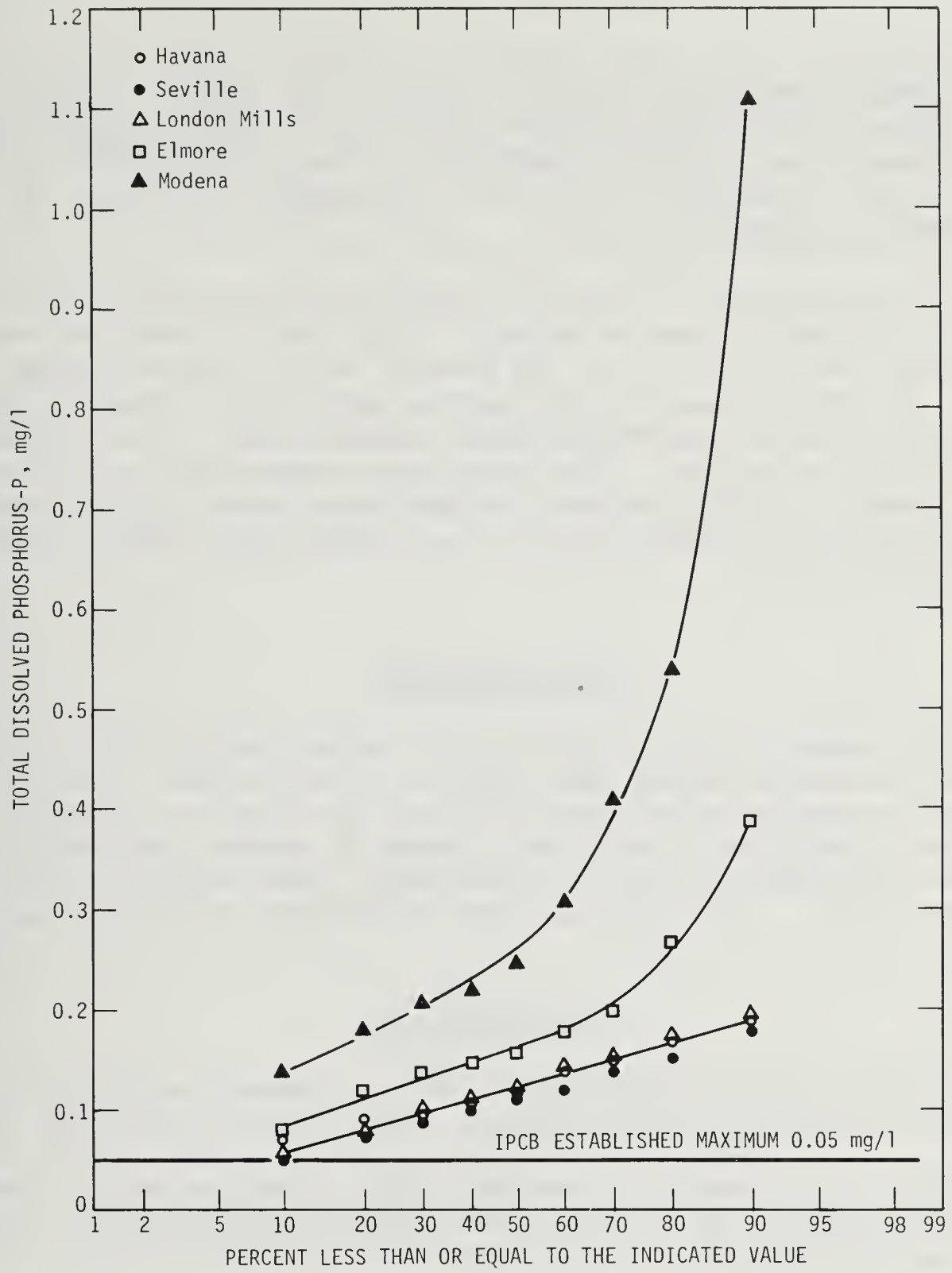

FIGURE 14.--Cumulative probability distribution of total dissolved phosphorus-P.

Illinois streams contain a substantial concentration of PO_4-P. The mean PO_4-P content of Peoria Lake in the Illinois River was reported as 1.13 mg/l (Sullivan and Hullinger, 1969). The mean concentrations of PO_4-P in the Middle Fork of the Vermilion River ranged from 0.17 to 0.45 mg/l depending on the sampling location (unpublished Water Survey data). The phosphorus concentrations in the Spoon River exceed the IPCB standard for phosphorus most of the time. Yet, it should be pointed out that the phosphorus content in the Spoon River is not unlike that found in many other streams in Illinois.

SUMMARY

The spatial and temporal variations of calcium, magnesium, manganese,

iron, phosphorus, silica, and sulfate in the Spoon River are presented for a two-year period from June 1971 through May 1973. Calcium and magnesium concentrations in the river water did not exhibit any spatial variations. Total iron concentrations in the river exceeded the IPCB limit of 1.0 mg/l about 90 percent of the time. Manganese concentrations were well within the stipulated limit.

The concentrations of dissolved phosphate-phosphorus and silica were highest in the Spoon River at Modena. This results from the proximity of the Modena sampling site to the Kewanee waste treatment plant discharges. The total dissolved phosphorus unit loads at Havana, Seville, London Mills, Elmore, and Modena were, respectively, 0.26, 0.27, 0.29, 0.36, and 0.47 lbs/ac/year. The phosphorus concentrations in the Spoon River exceeded the IPCB standard for phosphorus most of the time. Phosphorus content in the Spoon River is not unlike that found in many other streams in Illinois.

ACKNOWLEDGMENTS

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BODY COMPOSITION AND ORGAN WEIGHTS OF FOX SQUIRRELS[1]

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ABSTRACT

Organ weights and body composition values were determined for approximately 160 adult fox squirrels (Sciurus niger) collected in central Illinois from 1975 to 1977. Adult fox squirrel carcasses averaged 6.89 ± 0.37 percent fat, 67.62 ± 0.20 percent water, 12.52 ± 0.25 percent ash, and 4,829 ± 29 cal/g for energy. Most measured variables were significantly correlated with each other. The percentage of carcass fat is apparently the best single condition index for fox squirrels. In the field, the Riney kidney fat index provides a satisfactory quick estimate of fox squirrel condition. Female fox squirrels may require some minimum level of condition before entering estrus. Trapped squirrels that died from shock were in poor condition. The lens technique for aging fox squirrels may be inaccurate for individuals smaller than average size.

INTRODUCTION

Measures of body composition of an organism provide useful indices to its nutritional state and the biological and ecological demands placed upon it. Indicators of body condition allow comparison of organisms among populations, habitats, seasons, and diets.

Riney (1955) found that the kidney fat index was the most satisfactory index for red deer (Cervus elaphus). Monson et al. (1974) preferred the total kidney fat index for white-tailed deer (Odocoileus virginianus). Body fat levels have been used for indices in rodents (Gorecki, 1965; Jameson and Mead, 1964; Sawicka-Kapusta, 1968; Estep et al., 1974) and birds (Robel et al., 1974). Goldsmith et al. (1974) developed body weight-organ weight relationships in cottontails (Sylvilagus floridanus).

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Body composition, organ weights, and condition indices have not been reported for fox squirrels. The objectives of this study were to determine standards for organ weights and body composition for fox squirrels in central Illinois and to derive a condition index for fox squirrels.

METHODS

Fox squirrels were collected in central Illinois (mostly in Vermilion, Shelby, and Fayette counties) from August 1975 through April 1977 by hunting or livetrapping. Most squirrels were collected in the fall (August-October) and spring (February-April), thus precluding the determination of any annual trends in fox squirrel body condition or variables. Squirrels were aged by the lens technique (Beale, 1962) and by X rays of the epiphyseal cartilage of the forepaws (Carson, 1961).

The squirrels and body organs were weighed on Mettler and Ainsworth balances. The Riney kidney fat index (Riney, 1955) was determined by removing both kidneys with the adhering perirenal fat deposits and disregarding fat beyond the ends of the kidneys. Each kidney was weighed with and without the perirenal fat. Dividing the average perirenal fat weight by the average kidney weight and then multiplying by 100 provided the "Riney" index.

Female reproductive tracts were removed and frozen in water until processed. After thawing, each uterus was treated with a mixture of hydrochloric acid and potassium ferrocyanide to produce the Prussian blue reaction at the sites of placental scars (Humason, 1962:233).

After removal of body organs, the head, feet, and tail were removed from the carcass. All body cavity and mesentery fat deposits were left in the carcass. The carcass, skin and hair included, was then ground in a Hobart grinder until homogenous. Two 70-g carcass subsamples and the livers from each squirrel were dried to constant weight at 65°C and were then refluxed with petroleum ether in a Soxhlet apparatus for 3 days to extract lipids. The remainder of the carcass was freeze-dried to constant weight and ground to a fine powder in a Waring blender and Wiley mill with 20-mesh screen. Sub-samples of the carcasses were then analyzed for ash and energy. Ashing was done at 500°C in a muffle furnace for 12 hours. Energy determinations were made with a Parr Adiabatic Oxygen Bomb Calorimeter, Model 1200. Corrections were made for oxidation of fuse wire and acid formation. Percentages of fat and ash and caloric content of squirrel tissue were expressed on a dry-weight basis.

Linear correlation, linear regression, and *t*-tests of the means were used to evaluate the data; the 0.05 level of significance was used.

RESULTS AND DISCUSSION

Body Weight.--Adult male and female fox squirrels had almost identical average body weights. The average weight and standard error for adult females was 780.5 ± 9.2 g (N = 92); adult males averaged 775.1 ± 7.1 g (N = 115). Brown and Yeager (1945:468) found similar average weights for adult fox squirrels in Illinois, with males (771 g) weighing more than females (767 g). Short and Duke (1971:436) determined that adult male fox squirrels weighed significantly more than adult females in Texas. However, Chesemore (1975:205) noted that adult female fox squirrels in Oklahoma were significantly heavier than adult males. Baumgartner (1940:44) and Allen (1943:173) found that in Ohio and Michigan, respectively, female fox squirrels had higher average body weights than males. Discrepancies in male-female weight relationships may be a result of the reproductive condition of females.

Both sexes of adult fox squirrels in Ohio had a higher combined average body weight (793.5 g; Baumgartner, 1940:44) and Oklahoma squirrels had a lower average body weight (684.1 g; Chesemore, 1975:206) than Illinois squirrels (777.5 ± 5.7, N = 207). Michigan fox squirrels had an average body weight (765.5 g; Allen, 1943:173) comparable with that of Illinois squirrels.

Organ Weights and Body Variables.--Adult male and female fox squirrels had similar average values for organ weights and body composition variables (Table 1). However, females had a lower percentage of carcass fat, a higher Riney kidney fat index, and a significantly ($P < 0.05$) higher adrenal weight than males. The higher adrenal weight for females is probably related to stresses of reproduction. Shvarts (1975:149) reported that adrenals are much larger in female than in male animals, but Cowles et al. (1974:62) found no significant differences in adrenal weights between the sexes in gray squirrels (S. carolinensis).

In this study the average weight of a fox squirrel stomach plus its content was 14.55 g (Table 1). Baumgartner (1939:584) reported an average weight of 30.3 g for a fox squirrel stomach. Weeks (1974:333) found the content weight of one fox squirrel stomach to be 91.5 g and stated that stomach contents often composed 5-10 percent of the live weight of fox squirrels. In the present study, the average stomach and content weight comprised 1.9 percent of the average body weight of adults. The highest stomach and content weight I recorded was 80.9 g, which comprised 10.2 percent of the squirrel's body weight.

The mean litter size of fox squirrels in my study, based on placental scar counts, was 2.97 ± 0.12, with a range of 1 to 6 (Table 1). This average was similar to that recorded by other workers (Allen, 1943:118; Brown and Yeager, 1945:489; Packard, 1956:54; Chesemore, 1975:328).

The fat content in rodents can be a useful index of population processes (Sawicka-Kapusta, 1968). Fat content can vary with the physiological status, age, and sex of animals (Jameson and Mead, 1964; Kaufman and Kaufman, 1977) and with different seasons (Sawicka-Kapusta, 1968; Pucek, 1973).

Table 1. The mean, standard error, and sample size of body organ weights and physiological variables of adult male and female fox squirrels from central Illinois.[a] Numbers in parentheses indicate sample sizes.

Parameter	Sex		
	Male	Female	Both
Pancreas (g)	1.87 ± 0.06 (79)	1.75 ± 0.07 (70)	1.82 ± 0.04 (149)
Lungs (g)	9.04 ± 0.32 (81)	8.43 ± 0.32 (72)	8.75 ± 0.22 (153)
Heart (g)	4.05 ± 0.01 (88)	3.85 ± 0.09 (70)	3.96 ± 0.07 (162)
Liver (g)	17.75 ± 0.45 (80)	18.95 ± 0.72 (70)	18.31 ± 0.42 (150)
Stomach (g) and contents	15.33 ± 1.37 (81)	13.68 ± 1.45 (72)	14.55 ± 1.01 (153)
Adrenals (mg)	116.6 ± 4.0 (81)	149.5[b] ± 6.0 (73)	132.2 ± 4.0 (154)
Kidneys (g)	1.98 ± 0.04 (84)	1.98 ± 0.05 (73)	1.98 ± 0.03 (157)
Placental scars	-	2.97 ± 0.12 (66)	-
Percent carcass fat	7.56 ± 0.56 (59)	6.19 ± 0.48 (56)	6.89 ± 0.37 (115)
Percent carcass water	67.47 ± 0.21 (87)	67.80 ± 0.37 (72)	67.62 ± 0.20 (159)
Percent carcass ash	12.20 ± 0.33 (53)	12.93 ± 0.38 (42)	12.52 ± 0.25 (95)
Percent liver fat	9.80 ± 0.50 (79)	11.13 ± 0.61 (70)	10.43 ± 0.39 (149)
Carcass energy (cal/g)	4,857 ± 42 (42)	4,798 ± 39 (38)	4,829 ± 29 (80)
Riney index	27.19 ± 2.75 (84)	38.96 ±10.66 (73)	32.66 ± 5.14 (157)

[a] Approximate percentages, by sex and month of collection, of the total numbers of fox squirrels: January-February, 13 percent (male) and 4 percent (female); March, 14 and 10 percent; April, 40 and 38 percent; May-July, 0 and 5 percent; August-September, 20 and 21 percent; October-November, 10 and 21 percent; December, 2 and 1 percent.

[b] $P < 0.05$.

Body fat is usually highest in winter for nonhibernating, temperate zone rodents (Sawicka-Kapusta, 1968). In my sample, collected principally in fall and spring, the percentage of carcass fat was highest in February (12.63 percent) and lowest in August (4.48 percent). Adult fox squirrels in Illinois averaged 6.89 $\pm$ 0.37 percent carcass fat (Table 1) with a range of 1.3 to 21.6 percent for animals that appeared in good condition when collected in the wild. I found that squirrels confined to pens had carcass fat as high as 44.8 percent of their dry weight. Husband (1976:260) analyzed fox squirrels in Michigan for carcass fat but recorded higher values (7.28 to 36.92 percent) than those of wild squirrels in my study.

In small mammals, the percentage of body water is usually highest in the summer and lowest in the winter (Jameson and Mead, 1964; Gorecki, 1965; Sawicki-Kapusta, 1968; Pucek, 1973). My data reflect a similar pattern. The percentage of carcass water, varying inversely with carcass fat, was lowest in February (66.48 percent) and highest in August (69.26 percent). Carcass moisture averaged 67.62 percent (Table 1) as compared with averages of 66.8 to 75.0 percent for small mammals (Gorecki, 1965; Sawicka-Kapusta, 1968; Pucek, 1973; Kaufman et al., 1975; Bergeron, 1976).

Carcass ash values, which also varied inversely with carcass fat, were lowest in February (10.71 percent) and highest in August (14.21 percent). The mean ash value, 12.52 percent (Table 1), is similar to values given for small mammals (Gorecki, 1965; Kaufman et al., 1975).

The caloric value of animal tissue varies directly with its fat content (Gorecki, 1965:341). Thus, seasonal changes in body fat result in changes in the organism's caloric status. Energy content, like fat content, can, therefore, provide an index to the nutritional condition of an organism (Slobodkin and Richman, 1961:299). Male and female fox squirrels in Illinois had similar carcass energy values (Table 1). The average value of 4,829 cal/g dry weight for fox squirrel carcasses was lower than the value presented by Husband (1976:260) for fox squirrels but was comparable to values reported for small mammals (Gorecki, 1965: 345; Kaufman et al., 1975:947; Potter, 1975:53).

Gorecki (1965:349) recommended using a value of 1.5 kcal/g for the energy value of biomass for small mammals to calculate energy flow and productivity of populations. If we use the average percentage of moisture and the average caloric content of adult carcasses (Table 1), the calculated energy value of biomass for fox squirrels is 1.56 kcal/g, closely approximating Gorecki's recommended value.

Correlations Among Body Variables.--Carcass energy of fox squirrels was significantly and positively correlated with the percentage of carcass fat and significantly and negatively correlated with the percentage of carcass water and carcass ash (Table 2). Others have reported similar relationships in mammals (Kaufman et al., 1975:948; Husband, 1976:261; Fehrenbacher and Fleharty, 1976:189). The percentage of carcass fat is significantly and negatively correlated with the percentage of carcass water, as was found by Morton (1975:128), Husband

Table 2. Linear correlation coefficients of fox squirrel body variables. Sample sizes varies from 76 to 206.

	Variables						
Variables	Percent Carcass Fat	Percent Carcass Water	Percent Carcass Ash	Carcass Energy	Percent Liver Fat	Adrenal Weight	Riney Index
Percent carcass fat	1.00	-0.79[a]	-0.47[a]	0.74[a]	0.25[a]	-0.19[a]	0.72[a]
Percent carcass water	-0.79[a]	1.00	0.24[a]	-0.52[a]	-0.06	0.04	-0.61[a]
Percent carcass ash	-0.47[a]	0.24[a]	1.00	-0.47[a]	-0.07	0.13	-0.42[a]
Carcass energy	0.74[a]	-0.52[a]	-0.47[a]	1.00	0.08	0.05	0.58[a]
Percent liver fat	0.25[a]	-0.06	-0.07	0.08	1.00	-0.07	0.17[a]
Adrenal weight	-0.19[a]	0.04	0.13	0.05	-0.07	1.00	-0.17[a]
Riney index	0.72[a]	-0.61[a]	-0.42[a]	0.58[a]	0.17[a]	-0.17[a]	1.00

[a] $P < 0.05$.

(1976:261), Fehrenbacher and Fleharty (1976:189), and Kaufman and Kaufman (1977:432). Adrenal weight was negatively and significantly correlated with the percentage of carcass fat and the Riney kidney fat index, thus indicating that animals with a good supply of carcass fat tend to have low adrenal weights.

Condition Indicators.--In fox squirrels, fat and energy variables considered as condition indicators are all positively and significantly correlated among each other except the percentage of liver fat (Table 2). Liver fat does not appear to be as good an indicator of body condition as does carcass fat, carcass energy, or the Riney kidney fat index. The percentage of carcass fat appears to be the best indicator of condition because it has the highest correlation values among all the variables examined (Table 2). However, extraction procedures make it impractical to obtain the percentage of carcass fat under field conditions.

The Riney kidney fat index was significantly and positively correlated (r = 0.72) with the percentage of carcass fat in fox squirrels (Table 2). The linear regression of the percentage of carcass fat on the Riney kidney fat index is given in Figure 1. The mean values for the percentage of carcass fat and the Riney kidney fat index for 186 fox squirrels of all ages were 7.58 and 33.19 percent, respectively. The highest values for these variables that I found for wild squirrels were 21.6 percent for carcass fat and 85.3 for the Riney index. The lowest values were 0.4 percent for carcass fat and 0.0 for the Riney index in a squirrel that died from shock.

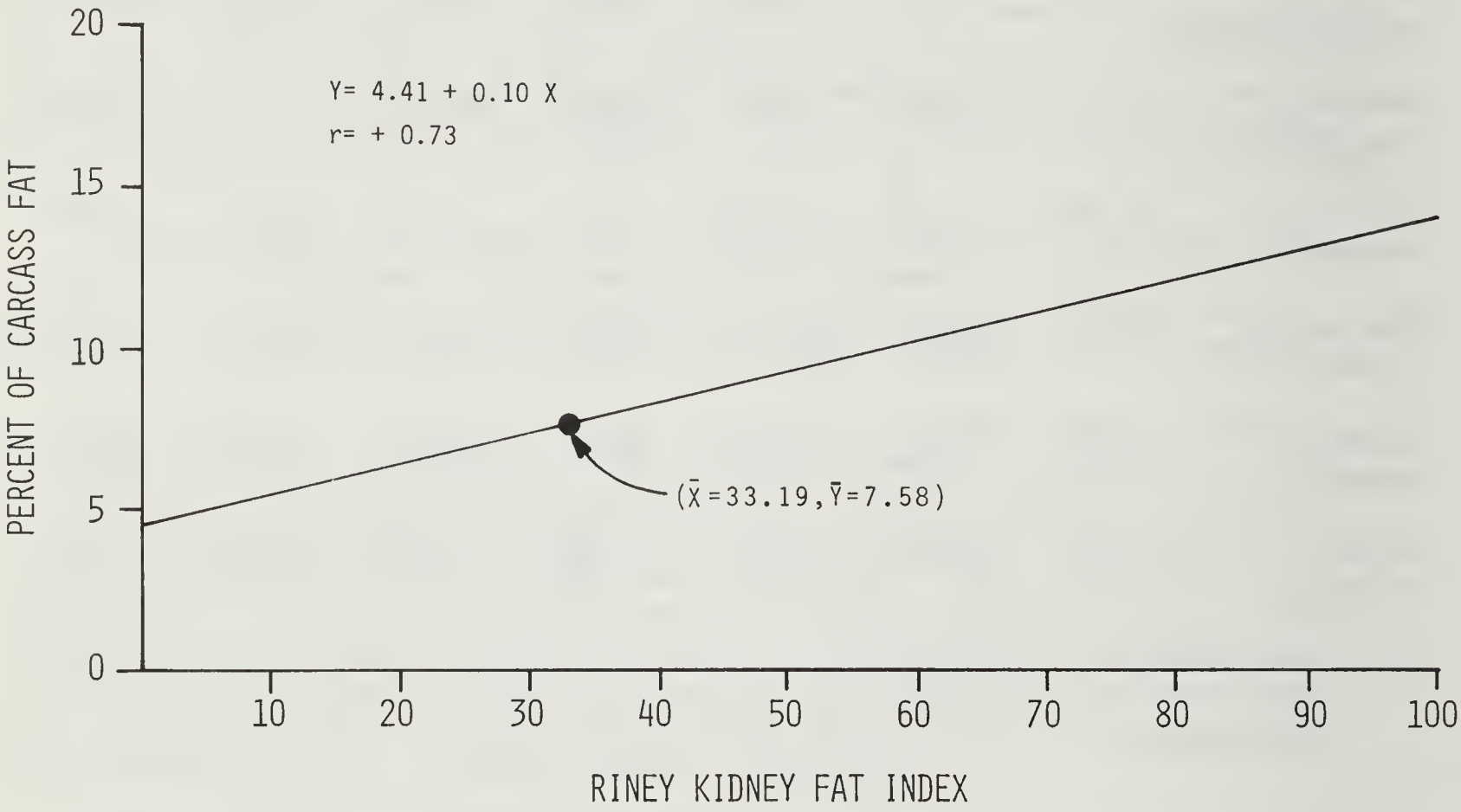

Figure 1. Relationship between the Riney kidney fat index and the percentage of carcass fat in fox squirrels ($P < 0.001$, 184 df).

Although the Riney kidney fat index can be used in field situations, it may have high variability (Table 1). Dauphiné (1975) found that the Riney kidney fat index was not suitable for caribou (Rangifer tarandus) because of a 70 to 80 percent seasonal variation in kidney weight. However, kidney weights in adult fox squirrels in Illinois varied a maximum of 20 percent for males and 32 percent for females. During the months when squirrels were collected, the kidneys weighed the

least during August and maintained a relatively stable level from October through April. The Riney kidney fat index should be suitable for a field estimation of the physical condition of fox squirrels at least during the period of October through April.

The following values for the percentage of carcass fat can be used as an index to estimate the physical condition of fox squirrels: 0-4.5 percent, poor; 4.5-8.5 percent, normal; above 8.5, excellent. Riney kidney fat index values and corresponding estimations of physical condition are 0-15, poor; 15-40, normal; above 40, excellent.

Fall vs. Spring Comparisons.--Allen (1943:172) considered winter to be the critical period for fox squirrels, especially because it includes a breeding season. Fox squirrels have been fed corn (Zea mays) in winter to enhance their physical condition, reproduction, and survival (Baumgartner, 1940; Allen, 1943; Havera, 1978). To differentiate physical variables for adult wild fox squirrels in timbered areas between fall and spring, squirrels collected before winter (August-November) and after winter (March-April) were compared (Table 3). Adults collected in the fall had a significantly ($P < 0.05$) higher percentage of liver fat than those collected in spring, whereas spring-collected adults had a significantly higher percentage of carcass fat than specimens collected in fall (Table 3). Spring squirrels, because of a higher fat content, correspondingly had lower percentages of carcass water and ash and higher carcass energy than fall squirrels. Fox squirrels collected in the fall had a slightly higher mean body weight and Riney index. Apparently, adults in the springs of 1976 and 1977 were in as good, if not better, physiological condition as adults during the preceding falls.

Comparison of Females in Different Reproductive Conditions.--Frisch and McArthur (1974:950) postulated that some minimum level of stored energy is necessary for ovulation and menstrual cycles in the human female. Reproductively active (pregnant or lactating) adult fox squirrels had higher average percentages of carcass fat than either postlactating or reproductively inactive adult females (Table 4). Pregnant fox squirrels had the highest average value of carcass fat, 8.37 percent, a value higher than that for all adult females (6.19) and for adult males (7.56) (Table 1). Evans (1973:15) found that breeding female meadow voles (Microtus agrestis) have significantly more fat than either breeding males or females outside the breeding season. It is possible that some minimum level of body fat may be needed for fox squirrels to enter estrus. However, it is also possible that increases in fat occur in fox squirrels during pregnancy as a result of the effects of estrogen (Nalbandov, 1964:193). The reproductively inactive females had a lower percentage of carcass fat (5.50), liver fat (7.73), and Riney index (23.78) than the averages for all adult females (Tables 1, 4). The sample size for reproductively inactive females is low, but it is possible that a subnormal body condition may explain their lack of breeding.

Table 3. The mean, standard error, and sample size of body variables of adult fox squirrels collected in the fall (August-November) and in the spring (March-April). Numbers in parenthesis indicate sample sizes.

Variables	Fall 1975-76	Spring 1976-77
Body weight (g)	788.0 ± 8.1 (51)	774.3 ± 9.1 (91)
Percent carcass fat	4.93[a] ± 0.35 (34)	7.22 ± 0.48 (67)
Percent carcass water	69.05 ± 0.23 (33)	67.99 ± 0.14 (82)
Percent carcass ash	13.64 ± 0.39 (30)	12.69 ± 0.43 (26)
Percent liver fat	12.70[a] ± 0.89 (30)	9.69 ± 0.57 (81)
Adrenal weight (mg)	132.9 ± 7.6 (34)	136.7 ± 5.3 (80)
Riney index	23.10 ± 1.77 (32)	19.48 ± 2.86 (82)
Carcass energy (cal/g)	4,765 ± 40 (29)	4,841 ± 64 (16)

[a] $p < 0.05$.

Carcass fat decreased noticeably in postlactating fox squirrels, possibly because of the high energy demands of lactation (Table 4). Millar (1975) found a significant decrease in body fat of white-footed mice (Peromyscus leucopus) during lactation. The stress of lactation in fox squirrels is also suggested by the low average Riney index value, high weight of adrenals, and high liver weights during lactation (Table 4). Shvarts (1975:134) stated that the liver weight in pregnant and lactating small mammals is higher than in males because a source of glycogen is necessary as food for the young. In fox squirrels, the

Table 4. The mean, standard error, and sample size of selected body organ weights and physiological variables of pregnant, lactating, postlactating, and reproductively inactive adult female fox squirrels. Numbers in parentheses indicate sample sizes.

Variables	Reproductive condition			
	Pregnant	Lactating	Postlactating	Inactive
Percent carcass fat	8.37a[a] ± 1.74 (10)	6.13a ± 0.55 (30)	4.65a ± 0.88 (10)	5.50a ± 1.14 (4)
Percent carcass water	67.58a ± 0.46 (10)	68.81a ± 0.76 (35)	69.20a ± 0.47 (10)	68.67a ± 0.38 (4)
Percent liver fat	10.40a ± 1.26 (9)	12.14a ± 0.95 (35)	12.83a ± 1.09 (10)	7.73a ± 3.16 (3)
Liver weight (g)	19.20ab ± 1.81 (9)	20.89a ± 1.13 (36)	13.98b ± 0.71 (9)	17.07ab ± 2.90 (3)
Riney index	32.49a ± 5.69 (10)	16.70b ± 1.44 (36)	25.94ac ± 2.52 (10)	23.78abc ±14.59 (4)
Adrenal weight (mg)	146.7a ±16.3 (9)	160.5a ± 9.0 (37)	138.1a ±12.3 (10)	124.3a ±23.31 (4)

[a] Within each row, values followed by the same letters do not differ significantly ($P < 0.05$).

average liver weight for pregnant and lactating females was higher than that for postlactating and reproductively inactive females. A significant decrease in average liver weight occurred between lactating and postlactating squirrels (Table 4).

Shock.--Analyses of 31 fox squirrels that died from shock in live traps showed that these animals were in poor condition (Table 5). Twenty-four of these squirrels were adults and many died in the fall when ample food was available. Pack et al. (1967:726) indicated that socially lower-ranked gray squirrels may suffer a higher shock mortality during trapping than higher-ranked squirrels. Baumgartner (1940:169) noted that fox squirrels that died from shock in live traps showed no apparent internal or external abnormalities. However, Guthrie et al. (1967) found that hypoglycemia and elevated packed-cell volumes were characteristic of gray squirrels in shock.

Table 5. The mean and standard error of selected body variables of fox squirrels that died from shock in live traps.

Variables	Squirrels Dead from Shock (N = 31)
Percent carcass fat	1.84 ± 0.34
Percent carcass water	68.41 ± 0.22
Percent liver fat	4.15 ± 0.39
Riney index	9.25 ± 3.87
Adrenal weight (mg)	142.0 ± 8.8

When compared with average fox squirrel values (Table 1), individuals that died from shock had significantly lower average values for the percentage of carcass fat (1.84) and liver fat (4.15) and for the Riney kidney fat index (9.25) (Table 5). The percentage of carcass fat in these squirrels ranged from 0.40 to 5.88 percent, but most values were under 2.00 percent. The average weight of adrenals was also higher in the squirrels that died from shock. Most of these squirrels were confined in live traps overnight when ambient nightly temperatures were abnormally low. Apparently, these squirrels, when stressed by confinement, were unable to mobilize sufficient energy to maintain their body functions.

Twenty-one fox squirrels, 11 of which were used for the carcass analyses reported in Table 5, died from shock after being retrapped within 10 days of a previous capture. These 21 squirrels lost an average of 11.2 percent (83.2 g) of their body weight between first captures and death. Thus, livetrapping appears to induce a severe physiological stress in some squirrels, particularly when forced to remain overnight in live traps during unusually cold weather.

Lens Weights.--Beale (1962) presented an age-lens weight curve for fox squirrels. Six fox squirrels were born in captivity during my study, two of which were sacrificed at 1 year of age. These two squirrels had average lens weights of 38.0 mg and 38.1 mg, which correspond closely to Beale's (1962:209) lens curve. The remaining four squirrels were sacrificed at 2 years of age; their average lens weights were 46.5 mg, 44.9 mg, 44.9 mg, and 36.3 mg. The first three lens weights agree with Beale's curve, but the last is less than the expected weight for a 1-year-old squirrel. The 2-year-old squirrel with the average lens weight of 36.3 mg weighed only 663 g, the least of all six known-age squirrels. A fox squirrel with three embryos when collected had an average lens weight of 33.3 mg, which, according to Beale's age curve, is a subadult squirrel approximately 6.5 months old. Female fox squirrels normally breed the first time when they are between 10 and 18 months old, and precocial breeding is rare (Allen, 1943:112; Brown and Yeager, 1945:475). However, this pregnant squirrel also weighed only 633 g, well below the 780.5 g average that I found for adult female fox squirrels. When squirrels are small because of genetic or other reasons, it appears that they may also have low lens weights relative to their ages. In these cases, an inaccurate age classification would result if the lens technique were used. For the lens technique to be useful in aging squirrels, it may be necessary to include some correction for body size, possibly body length.

CONCLUSIONS

The intent of this study was to present average values for some physiological variables of fox squirrels. These data may be useful for comparisons of fox squirrels in various stages of their life cycle, to evaluate the physical status of a population of fox squirrels, and possibly to explain increases in disease and mortality or a decrease in reproduction. Thus, a fox squirrel population with a low percentage of carcass fat during the winter breeding season may be expected to show reduced reproduction in the spring and perhaps a decline in abundance or an increase in disease. The percentage of carcass fat may provide a fairly reliable index to the condition of fox squirrels and any associated ecological implications.

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BATS OF THE CAVES AND MINES OF THE SHAWNEE NATIONAL FOREST, SOUTHERN ILLINOIS

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Bats are not abundant in winter in caves and mines of the Shawnee National Forest, but the species most commonly found are the Pipistrelle, Pipistrellus subflavus, the Little Brown Bat, Myotis lucifugus, the Big Brown Bat, Eptesicus fuscus, and Keen's Bat, Myotis keenii. There is a large summer colony of gray bats, Myotis grisescens, in Cave Spring Cave, Hardin County. Myotis austroriparius occurs sparingly in the Forest, while a very few individuals of Plecotus rafinesquii and Lasionycteris noctivagans hibernate in the silica mines of Alexander and Union counties. A hibernating colony of the Indiana bat, Myotis sodalis, once occurred in Cave Spring Cave in Hardin County, but this species is apparently now absent from the forest. Ectoparasites taken were the mites Macronyssus crosbyi, M. jonesi, Spinturnix americanus, S. banksi, S. globosus, Olabidocarpus whitakeri, Acanthophthirius gracilis; the chigger, Euschoengastia pipistrelli; and the flea, Myodopsylla insignis.

INTRODUCTION

This study was initiated and financed by the U.S. Forest Service to determine the distribution and abundance of bats occurring in the Shawnee National Forest of southern Illinois. It should provide data useful for further assessment of bat population changes. A small amount of information is presented on ectoparasites of the species also.

Previous papers containing information on bats of the Shawnee Forest are Smith and Parmalee (1954), Layne (1958), Pearson (1962), Hall (1962), and Hall and Wilson (1966).

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MATERIALS AND METHODS

There are relatively few caves on the Shawnee as compared to southern Indiana (Bretz and Harris, 1961), but there are large numbers of fluorspar mines on the east (Hardin County) and silica mines in the west (Alexander and Union Counties). During winter all 18 larger caves, and 5 small caves, 30 silica mines and 5 fluorspar mines were examined. The fluorspar mines are very extensive and were not examined completely, but all were explored for several hundred yards. Some cave and mine entrances were mistnetted during summer. All caves and mines examined are listed in the full report on file with the Forest Service at Harrisburg.

RESULTS

During the present study, 18 large caves, 5 small caves, 12 overhangs, and 36 mines were examined during winter. Of the 71 openings, 28 harbored bats (13 caves and 15 mines). No overhangs and only one small cave harbored bats.

Nineteen abandoned silica mines harbored no bats. These were mostly small single passage mines, many of them less than 150' long, and quite dry. Most of the larger silica mines harbored bats. Two of the larger fluorspar mines and four larger caves were examined in which no bats were found, Griffith Cave, Frieze Cave, Big Creek Cave, and Brown's Hole. Big Creek and Frieze Caves probably lacked bats because they appear to fill completely during flooding, although a few bats were taken in Big Creek Cave by James N. Layne, 27 Dec. 1954. Griffith Cave was especially surprising in not harboring bats as bats have used this cave in the past, and also, it has large rooms. Likely reasons for the lack of bats were its present dryness and easy access to human visitation

The 11 silica mines yielded 109 bats of six species (Table 1). *Eptesicus* and *Pipistrellus* each occurred in 8 of the 11 mines, *Pipistrellus* being the most abundant. The three fluorspar mines with bats in Hardin County yielded four species, none in large numbers; the large limestone mine yielded three big brown bats. Thirteen caves examined during winter yielded bats; all contained pipistrelles, which ranged from 1 to 24 per cave ($\bar{x} = 6.77$). Nine caves yielded only pipistrelles, including Cave Spring Cave, which in the 1950's harbored *Myotis sodalis*

TABLE 1. Hibernating bats of the caves and mines of the Shawnee Forest found to contain bats.

	No. of bats	Ave. # per cave or mine	No. of caves or mines	% of caves or mines
13 Caves				
Myotis lucifugus	199	15.31	4	30.8
Pipistrellus subflavus	88	6.77	13	100.0
Eptesicus fuscus	12	0.92	2	15.4
Myotis austroriparius	1	0.08	1	7.7
11 Silica Mines (Alexander and Union Counties)				
Pipistrellus subflavus	50	4.54	8	72.7
Myotis lucifugus	27	2.45	4	36.4
Eptesicus fuscus	19	1.73	8	72.7
Myotis keenii	11	1.00	3	27.3
Myotis austroriparius	1	0.09	1	9.1
Plecotus rafinesquii	1	0.09	1	9.1
3 Fluorite Mines (Hardin County)				
Myotis lucifugus	5	1.67	2	66.7
Pipistrellus subflavus	3	1.00	1	33.3
Eptesicus fuscus	5	1.00	2	66.7
Myotis keenii	1	0.33	1	33.3
1 Limestone Mine (Rhine mine)				
Myotis lucifugus	2	2	1	100.0

(Layne, 1958) and which still had a large summer population of Myotis grisescens. The four caves with bats other than Pipistrellus were Rich's Cave, Bat Cave, Brasel's Cave and Guthrie Cave.

Mistnetting of the three openings of Crystal mine (Hardin Co.), at Cave Spring Cave (Hardin Co.), and at Rich's Cave (Union Co.) occurred on 27-29 August 1974 (Table 2). Cave Spring Cave was also explored at this time, when a large colony of gray bats, Myotis grisescens, was observed. Six species of bats were taken by mistnetting at Cave Spring Cave, including eight M. austroriparius and 80 M. grisescens; the number of individuals would have been much higher there except for the rain when netting occurred. Five species of bats were netted at Crystal Mine and four at Rich's Cave.

Data on mines and caves with hibernating bats is given in Table 3.

STATUS OF THE BATS

Pipistrellus subflavus, Myotis lucifugus, M. keenii and Eptesicus fuscus are the most common cave bats of southern Illinois and on the Shawnee Forest (Tables 1-3). During the present study, no Keen's bats were seen in caves (Table 1), eleven were in silica mines, one was in a fluorspar mine and 15 were netted (Table 2).

Myotis austroriparius. Southeastern bat.

Myotis austroriparius was first reported from Illinois by Smith and Parmalee (1954), although Wayne H. Davis banded three individuals just inside the entrance at Cave Spring Cave 29 Nov. 1953 (pers. comm.). Smith and Parmalee (1954) reported two individuals from 2½ miles NW of Cave-in-Rock, but it is not clear whether they were from the Forest. The same authors also reported 17 individuals from ½ mile NE of Rosiclare. These must have been from Layoff Cave, just outside the Forest. Layne (1958, and field notes) collected 14 individuals in three natural caves, but none in silica mines or prospect shafts. Layne recorded several individuals in Layoff Cave and Cave Spring Cave on 21 Dec. 1954 and a few in Rich's Cave, on 5 Feb. 1955. Hoffmeister took this species in Hardin County, 10 Nov. 1962, probably in the Crystal Mine area (pers. comm.).

During this study, seven individuals were netted at Cave Spring Cave and one at Crystal Mine (Hardin Co.). A hibernating individual was in Rich's Cave, and another was in a silica mine in Union County, 4 miles NW of Mill Creek.

Myotis grisescens. Gray bat.

This species concentrates in winter in a very few caves. Cory (1912), Miller and Allen (1928) and Necker and Hatfield (1941) refer to specimens from Rosiclare, Hardin Co., Illinois. These references likely are all from Cave Spring Cave, and there are specimens from this cave in the University of Illinois mammal collection taken 6 August 1950 (pers. comm. D. F. Hoffmeister). Southern Illinois University has

TABLE 2. Mistnetting at cave and mine entrances on Shawnee Forest, 27, 28, and 29 August 1974.

Species	No. of bats	Av. # per hr.
3 entrances at Crystal Mines, 27 Aug. 1974 (total combined time of netting 14.5 hrs). Temperature 75° at 9:45. Two short rainstorms.		
Pipistrellus subflavus	9	0.62
Eptesicus fuscus	9	0.62
Myotis keenii	4	0.28
M. lucifugus	1	0.07
M. austroriparius	1	0.07
	24	1.66
Cave Spring Cave, 28 Aug. 1974. Time 4 hrs. 20 min. Much hard rain. Temperature 75-80°.		
Myotis grisescens	80	18.46
M. lucifugus	12	2.77
M. austroriparius	7	1.62
Pipistrellus subflavus	6	1.38
Myotis keenii	3	0.69
Eptesicus fuscus	1	0.23
	109	25.15
Rich's Cave, 29 Aug. 1974. Time 4 hrs. 45 min. Temperature 72°.		
Myotis keenii	8	1.80
Eptesicus fuscus	6	1.35
Myotis lucifugus	5	1.12
Pipistrellus subflavus	1	0.69
	20	4.49

TABLE 3. Complete listing of hibernating bats from caves and mines of the Shawnee National Forest, 1974.

	Pipistrellus subflavus	Myotis lucifugus	Eptesicus fuscus	Myotis keenii	Myotis austro-riparius	Plecotus rafinesquii	Total
Alexander County							
Silica mine #31	4	1	1				6
Silica mine #32	4		1				5
Silica mine #33			3				3
Silica mine #38	1		3				4
Silica mine #41	4	5					9
Silica mine #83			1				1
Silica mine #88	9			1			10
Hardin County							
Cave Spring Cave--							
Lower entrance	9						9
Fluorite mine #54	3	2					5
Fluorite mine #55		3	2	1			6
Fluorite mine #66			3				3
Rhine mine		2					2
Jackson County							
Ava Cave	11						11
Black Cave	24						24
Bat Cave	1	40	11				52
Pope County							
Brasher Cave	5						5
Cave #72	1						1
Saline County							
Equality Cave	1						1

TABLE 3 - continued

	Pipistrellus subflavus	Myotis lucifugus	Eptesicus fuscus	Myotis keenii	Myotis austro-riparius	Plecotus rafinesquii	Total
Union County							
Brasel's Cave	17	7					24
Guthrie Cave	5	1					6
Lilly Cave	9						9
Rich's Cave	3	151	1		1		156
Silica mine #39	19	13					32
Silica mine #40	4	8	8	7	1		28
Silica mine #84			1				1
Silica mine #85	5		1	3		1	10
Union Point Cave	2						2
	141	233	36	12	2	1	425

three specimens collected there in 1955 (pers. comm. J. W. Hardin). Hall and Wilson (1966) found about 10,000 gray bats in Cave Spring Cave.

Smith and Parmalee (1954) collected five individuals 1 Oct. 1953 from a small cave (now called Twin Culvert Cave) four miles E of Nebo, Pike County, Illinois, approximately 200 miles NW of Hardin County, and the northernmost locality for this species. This cave was visited by the same workers June 25, and twice in December the same year, but no gray bats were found. One from "4 miles SW of Pearl, Pike County" in the University of Illinois mammal collection (pers. comm. D. F. Hoffmeister) also originated in Twin Culvert Cave, and Kerr (1973) and Skaggs (1973) found this and three other caves and mines in Pike and Adams Counties to be spring and fall stations for migrating gray bats. Southern Illinois University has a gray bat collected in 1956 from Griffith Cave (pers. comm. J. W. Hardin).

Gray bats from Kentucky, Tennessee and Illinois hibernate in one cave complex, Coach-James Cave, Edmonson County, Kentucky (Hall and Wilson, 1966), where the winter colony appears to include about 100,000 bats, and one of five bats banded by Hall and Wilson from the Cave Spring Cave colony was recovered in Coach-James Cave, 126 miles to the east.

On 28 August 1974, Cave Spring Cave contained an estimated 1000-2000 gray bats a few hundred feet inside. They formed a compact mass, about 1½ by 5 feet. Guano was piled directly below the mass, and was abundant on the rocks and water throughout the cave. Unfortunately, it rained very hard that night, and bats were not overly active, but a mistnet at the entrance yielded 80 gray bats, along with a few individuals of other species (Table 2). On 4 Dec. 1974, the cave was again visited, but no gray bats were present, and gray bats were not found elsewhere during this study.

Myotis sodalis. Indiana bat.

Myotis sodalis has never been abundant in Illinois. The first record is in the original description of the species (Miller and Allen, 1928), who reported specimens from "Rosiclare." Necker and Hatfield (1941) report a specimen in the Field Museum from the same locality. Probably these specimens are all from Cave Spring Cave. There are records from Jo Daviess County (Smith and Parmalee, 1954), Pike and Morgan Counties (pers. comm. D. F. Hoffmeister), Cook County (Hall, 1962), and LaSalle County, all outside the Shawnee Forest. The LaSalle County record is for Blackball Mine, which contains the only known colony of this species presently existing in Illinois.

On 29 November 1953, Wayne H. Davis banded 80 Indiana bats from crevices in the room just inside the entrance to Cave Spring Cave. On 21 December 1954, and on 12 March 1955, James N. Layne found two groups of the banded bats jammed in crevices in the same room. John S. Hall found one M. sodalis in 1957 (2 visits), and two in 1958 (several visits, Hall, 1962), all in the same room. There are no later published records of this species in Cave Spring Cave.

On 31 December 1954, Layne (1958) took a single female in Guthrie Cave, Union County. Pearson and Barr (1962) report one individual from Pulaski, Union or Alexander County.

On 8 March 1974, we entered Cave Spring Cave beyond the area where M. sodalis once wintered. Only two Pipistrellus subflavus were found. On 28 August 1974, we explored the entire cave and found M. grisescens and Pipistrellus. That night the entrance was netted (Table 3). M. sodalis was not found among the 109 individuals of six different species of bats taken. On 4 December we again explored the entire cave and found seven hibernating Pipistrellus.

During this study, no Indiana bats were found, either by summer mistnetting or by examination in winter of caves or mines.

Plecotus rafinesquii. Big-eared bat.

Cory (1912) stated that this species had not been recorded from Illinois, but should be looked for in the caves along the Ohio River in Hardin and Pope Counties. Elder (1946) found one on 5 October 1962, near Elco, Alexander County. Smith and Parmalee took one from an abandoned silica mine near Olive Branch, 2 February 1954. Layne (1958 and field notes) took one male and one female on 30 January 1955, and Pearson (1962) took 13 individuals in 9 mines.

We found only one big-eared bat. It was hibernating in a large silica mine in Union County (6 December 1974).

Lasionycteris noctivagans. Silver-haired bat.

Lasionycteris noctivagans is normally considered to be a tree bat, but occasionally hibernates in buildings, caves and mines. Smith and Parmalee (1954) took three hibernating individuals on 27 January 1954, and one on 2 February from a silica mine near Elco. On 12 February 1955, Layne found 4 in two silica mines, and Pearson (1962) found 18 silver-haired bats in eight mines (Alexander and Union Counties). No individuals were seen during the present study.

BAT POPULATION CHANGES

The common hibernating bats of the Shawnee Forest are Pipistrellus subflavus, Myotis lucifugus, Eptesicus fuscus, and Myotis keenii. Myotis austroriparius is much less common, whereas Plecotus rafinesquii and Lasionycteris noctivagans are very uncommon. Myotis sodalis originally hibernated in Cave Spring Cave, but no longer does. There is a summer breeding colony of M. grisescens in Cave Spring Cave. This colony is much smaller than in previous years, and the species is absent from Illinois during winter.

Other than for Myotis sodalis and M. grisescens, it is difficult to determine if there have been recent changes in Shawnee bat populations because (1) there are few bat counts given for specific caves or

mines, (2) it is difficult to separate yearly from long-term population changes, and (3) one cannot assess differences in thoroughness between studies.

We have two sets of data which give previous bat counts: the 1954-1955 field notes of Layne, and the 1962 data of Pearson. In the latter study, specific mines were not identified. Our assessment is based on a few selected caves and mines which Layne studied and on summarized information for the mines as a whole (Table 4).

Griffith Cave is short and dry with large rooms. It is close to houses and a road and is subject to frequent visitation. Layne on 27 December 1954 found one Myotis keenii, several M. lucifugus, two Pipistrellus subflavus, and three Eptesicus fuscus. A visit on 12 March 1955 yielded Myotis lucifugus and two Pipistrellus subflavus. During the present study, the single winter trip to Griffith Cave was on 8 March 1974. No bats were found, perhaps indicating a bat decrease.

On 5 February 1955, Layne found several Pipistrellus subflavus, one Eptesicus fuscus, one M. austroriparius, and several individuals and two groups of about 10 M. lucifugus in Rich's Cave. We visited this cave 26 February 1974 and found 151 Myotis lucifugus, 3 Pipistrellus subflavus, one Myotis austroriparius and one Eptesicus fuscus. Thus, no evidence of a decrease was noted for this cave. This was the greatest concentration of bats seen in winter in any cave or mine during the study.

Layne examined 15 silica mines in January and February, 1955 (Table 4), of which 11 (73%) had a total of about 102 bats (with the number 15 inserted for "common" in one instance, for fairly numerous in another, and the number 10 inserted twice for "several"). Pearson (1962) made 35 searches in 1958-1960, and 22 mines were examined during the present study (Table 4). Pearson found the highest average number per cave, the present study the second highest, and Layne the lowest. These data do not indicate any marked change in wintering populations of bats in the silica mines, although they may be indicative of a decrease in two of the less common species, Plecotus rafinesquii and Lasionycteris noctivagans.

ECTOPARASITES

Ectoparasites were obtained as follows (numbers in parentheses designate numbers of parasites taken).

Myotis austroriparius (6 examined)

Labidocarpid mites, Olabidocarpus whitakeri (3); macronyssid mites, Macronyssus jonesi (4) and M. crosbyi (1); unidentified chigger (1).

Myotis grisescens

Eleven taken 28 August at Cave Spring Cave, all with mites: macronyssid mite, Macronyssus jonesi (18); spinturnicid mites, Spinturnix

TABLE 4. Bats from silica mines, 1955, 1958-1960, and 1974. (Averages are numbers per mine with bats.)

	Layne 1955	Pearson* 1958-60	Present study
No. mines examined	15	35	22
No. with bats	11	24	11
Total # bats	102	356	112
Av. # bats/mine	9.27	14.83	10.18
Pipistrellus subflavus	85	211	50
Av. #/mine	7.72	8.79	4.54
Eptesicus fuscus	9	21	19
Av. #/mine	0.82	0.88	1.72
Lasionycteris noctivagans	4	18	0
Av. #/mine	0.36	0.75	
Myotis keenii	2	53	11
Av. #/mine	0.18	2.21	1.00
Plecotus rafinesquii	2	13	1
Av. #/mine	0.18	0.54	0.09
Myotis lucifugus	0	40	27
Av. #.mine		1.67	2.45

*Some mines were searched more than once by Pearson, each search treated here as a separate mine.

banksi (104), S. globosus (9), S. americanus (9); labidocarpid mite, Olabidocarpus whitakeri (425), myobiid mite, Acanthophthirius sp. (3).

Myotis keenii (1 examined)

Myobiid mites, Acanthophthirius gracilis (2); chiggers, Euschoengastia pipistrelli (5); macronyssid mite, Macronyssus crosbyi (1).

Myotis lucifugus (8 examined)

Chiggers, Euschoengastia pipistrelli (9); fleas, Myodopsylla insignis (4); macronyssid mite, Macronyssus crosbyi (1).

No external parasites were found on the two pipistrelles nor on the one big-eared bat examined.

Macronyssus jonesi, Spinturnix globosus, Olabidocarpus whitakeri and Acanthophthirius gracilis had not been previously reported from Illinois. New host records are Macronyssus jonesi on Myotis austroriparius, and Olabidocarpus whitakeri on M. grisescens.

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A SURVEY OF THE NIDULARIACEAE (BIRD'S NEST FUNGI) IN ILLINOIS

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ABSTRACT. Personal collections, herbarium material, and literature citations were studied to document the characteristics and more clearly delimit the distribution of the Nidulariaceae (Bird's Nest Fungi) in Illinois. Five species --Nidularia pulvinata (Schw.) Fries, Crucibulum laeve (Huds. ex Relh) Kambly, Cyathus olla Batch ex Pers., Cyathus stercoreus (Schw.) de Toni, and Cyathus striatus Huds. ex Pers.--occur in the state. Specimen-documented detailed descriptions, illustrations, and distribution maps, including several new county distribution records, are provided for each species.

The Nidulariaceae (Bird's Nest Fungi) are saprophytic fungi characterized by the production of basidiospores within peridioles which serve as dispersal units and are situated at maturity in a more or less cup-shaped peridium. To our knowledge, specimen-documented detailed descriptions and illustrations of Illinois material do not exist. Further, their occurrence and distribution in Illinois are poorly known. Therefore, we undertook this study utilizing personal collections, those available from other herbaria throughout the state, and, where necessary, citations in the literature to more clearly document their variation and delimit their range in Illinois.

Where possible, morphological data were taken from fresh material. Because there was little observed difference between fresh and dry specimens, some additional information was obtained from most dried collections. Color terms in quotation marks (e.g., "warm buff") are those of Ridgway (1912). Because Ridgway's terminology may be

unfamiliar to those lacking access to his color standard, approximations of his colors are included in general terms.

Periodioles were soaked in tap water to soften them and facilitate sectioning. Because no change in basidiospore size was apparent with soakings of 1-48 hours, a short period of 1-2 hours duration was routinely employed. Sections were made directly on microscope slides and mounted in 3% KOH. Ten random basidiospores were measured from each specimen, and the field was subsequently checked for variations from these measurements.

Unless otherwise noted by herbarium designations from Holmgren and Keuken (1974), collections examined are located in the Mycological Collections, Southern Illinois University Herbarium. Those housed in the personal herbaria of J. P. Dey (Department of Biology, Illinois Wesleyan University, Bloomington, IL) and D. S. Wujek (Department of Biology, Carl Sandburg College, Galesburg, IL) are indicated by the collector's initials (JPD and DSW, respectively).

Nidularia pulvinata (Schw.) Fries Figs. 1, 2, 7, 8, 13

Basidiocarps 1-4 mm tall, 3-10 mm broad at the apex, irregular and more or less cushion-shaped, not cup-like and not constricted at the base, lacking an emplacement. Outer peridial surface powdery-tomentose, dry; cinnamon ("cinnamon" to "cinnamon brown"). Inner surface, where visible, cinnamon to dark brown ("orange-cinnamon" to "chocolate brown"); without striations. Well-defined mouth and differentiated epiphragm lacking; opening by dissolution or fragmentation of the upper portions of the peridium.

Peridioles numerous, 1-1.2 mm broad; lenticular; smooth; chestnut brown ("sepia" to "chestnut brown"); embedded in a copious, dark, gelatinous material when fresh; funiculus lacking.

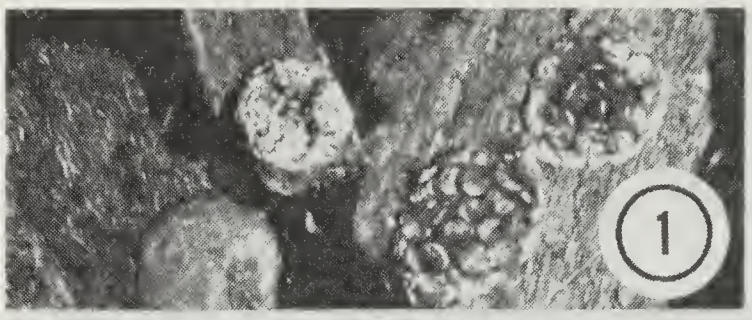
Basidiospores 6.0-12.5 x 4.5-6.9 µm; ovate; smooth; thin-walled; hyaline; interspersed with irregularly branched, hyaline, thick-walled (easily disarticulated inner cortical?) cells (Fig. 7).

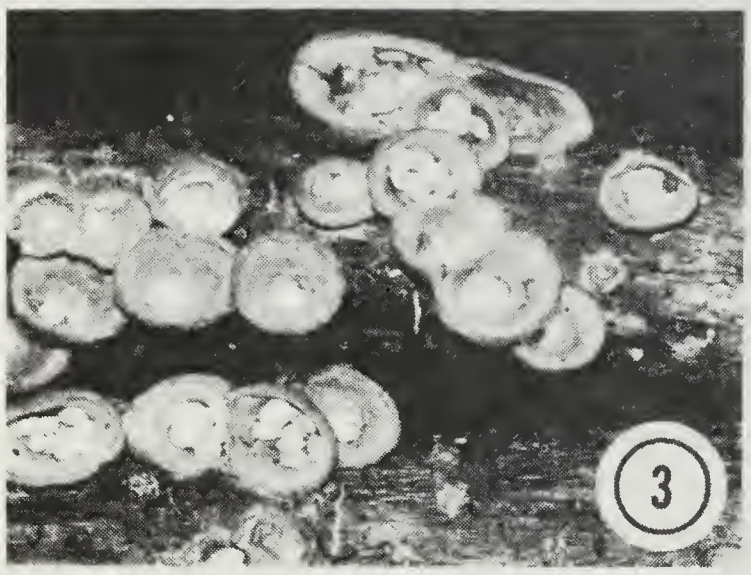
Habit and habitat: Scattered to gregarious on decorticated hardwood logs in wet lowland habitats. June to July.

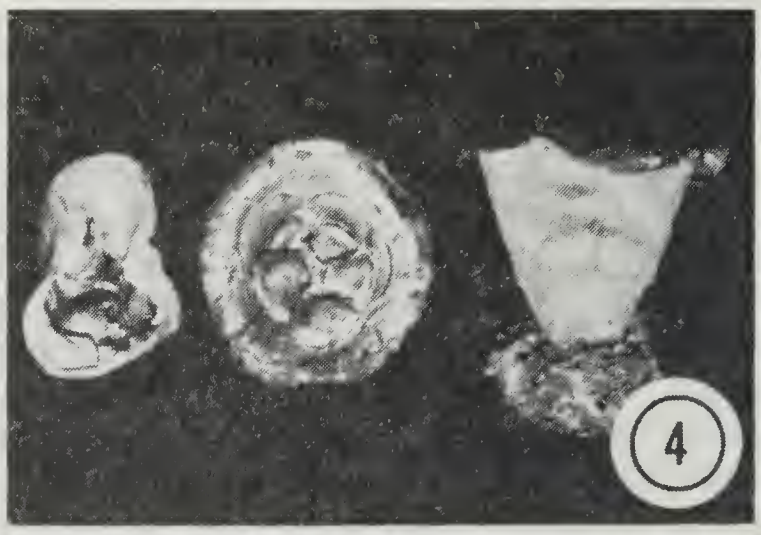
Material examined: Johnson Co.: Sundberg 3317. Lawrence Co.: Parker sn (EIU). Union Co.: Bandoni 3334.

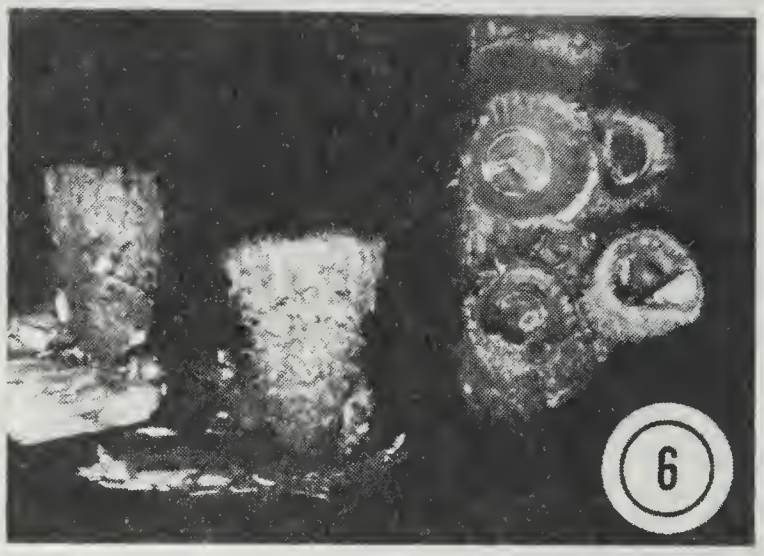
This species was previously reported in Illinois only from Lawrence Co. (Parker 1975).

Nidularia pulvinata can be distinguished by its small,









Figs. 1-6. Basidiocarps of species in the Nidulariaceae.

1, 2. Nidularia pulvinata. Sundberg 3317, X 3.5.
3. Crucibulum laeve. J. Schanzle 4, X 2.0.
4. Cyathus olla. Sundberg 1365, X 1.8.
5. Cyathus stercoreus. Waite 33, X 2.0.
6. Cyathus striatus. Parady 2, X 2.0.

irregular shape, the lack of a cup-shaped peridium, its numerous peridioles, and the copious gelatinous material (which is evident even when dry) surrounding the peridioles.

Crucibulum laeve (Huds. ex Relh) Kambly Figs. 3, 11, 14

Basidiocarps 2-11 mm tall; 2-8 mm broad at the mouth; subglobose to short and upright-cylindric, occasionally flaring out in the upper third; not constricted at the base, lacking a well-defined emplacement. Outer peridial surface buff to ochre ("warm buff" to "antimony yellow", rarely "dresden brown"); tomentose when young, becoming smooth with age. Inner peridial surface "pale ochre" at the base, grading into "cream" at the apex (rarely near "pale pinkish buff"); shiny; without striations. Margin of mouth glabrous. Epiphragm buff ("capucine buff" to "raw sienna") and tomentose when present.

Peridioles few; 1-2 mm broad; disk-shaped; smooth; dull buff ("light buff" to "warm buff"); funiculus present, attached to the peridium.

Basidiospores 5.6-13.5(-15.0) x (3.0-)4.2-7.5 µm; ovoid to occasionally ellipsoid, rarely oblong or pyriform; smooth; wall moderately thick; hyaline.

Habit and habitat: Caespitose to gregarious on decaying hardwood logs and leaves, occasionally on dung. Late May to late October.

Material examined: Cook Co.: Edgecombe sn (F nos. 1201835, 1201881, 1205936, 1205960, 1207705); Harper sn (F 1318780); Moffatt 1575 (F 1229062). DuPage Co.: Moffatt sn (F 1318780). Henry Co.: Harper sn (F nos. 1316250, 1322760, 1323027--the latter is a mixed collection). Jackson Co.: Bankson and Gilman 183; Burton 75; Engleman 21; Halbrendt 8; Parady 1, 3, 6, 8, 12; Schanzle 4; Sundberg 2055, 2078, 2217, 2224, 2394. Jefferson Co.: Waite 31. Jo Daviess Co.: Ozmont and DeFillips 0064; Steyermark 40808 (F 117990). Knox Co.: Wujek 358 (DSW). LaSalle Co.: Moffatt sn (F 1229050). McLean Co.: Dey 8260 (JPD), 8261 (JPD). Ogle Co.: Moffatt 1192 (F 1229018--a mixed collection). Pope Co.: West 264. Rock Island Co.: Harper sn (F nos. 1314719, 1316048, 1322838). Union Co.: West 191 (F 1020545). Williamson Co.: Borders 38; Koelsch 23; Sundberg 2959.

In addition to reports (counties not noted) by Lloyd (1906) and Murrill (1911), this species was previously noted from Champaign (Coker and Couch 1928), DuPage (Moffatt 1923), Jackson (French 1907, Bankson and Gilman 1963), Lawrence (Parker 1975), McLean (Cooke 1969), and Piatt (Cooke 1969, Parker 1975) counties.

Crucibulum laeve can be easily identified by its pale (almost white) peridioles and its broad-based peridium.

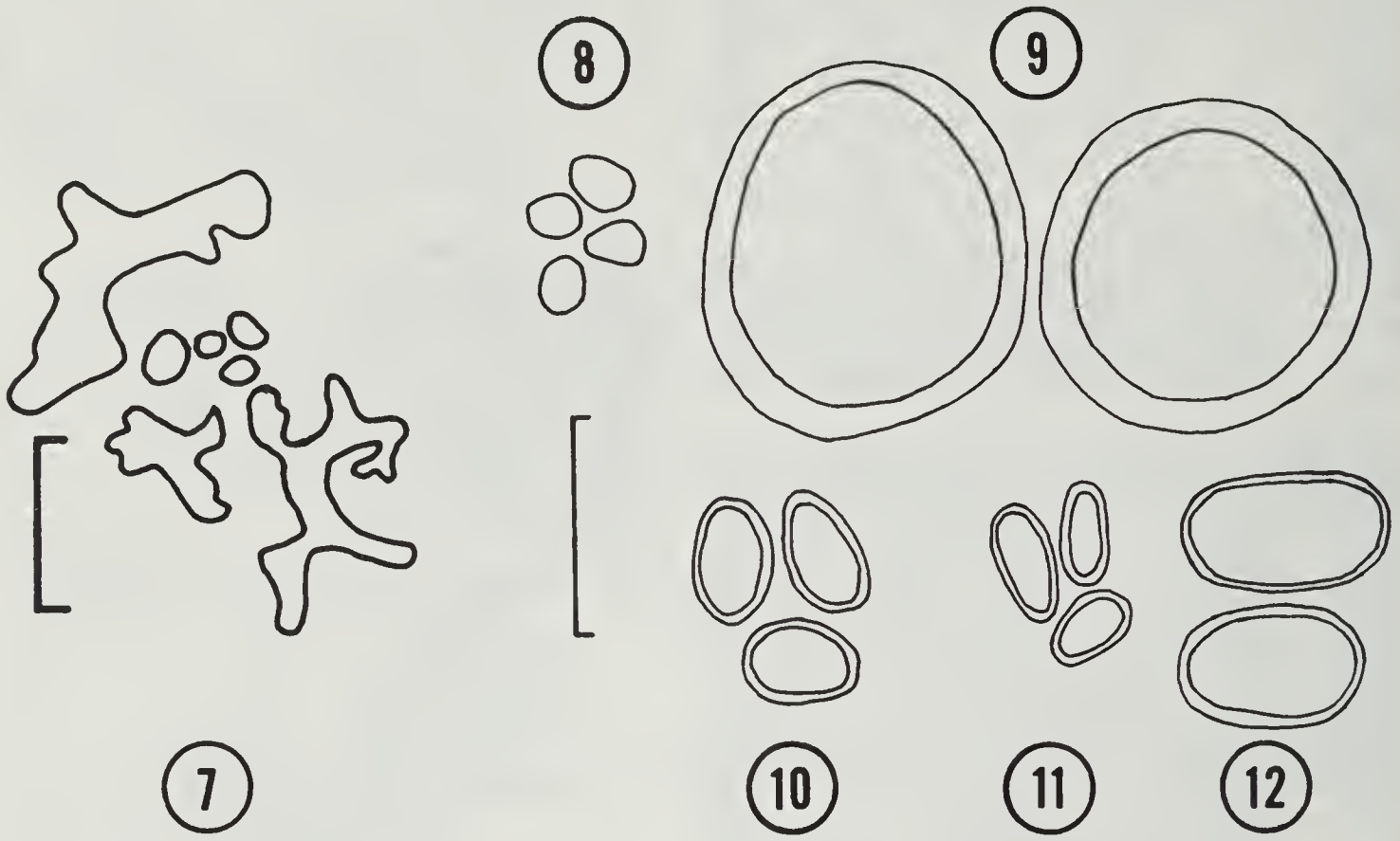


Fig. 7. Nidularia pulvinata. Irregularly branched cells found interspersed with basidiospores. Scale line equals 20 µm.

Figs. 8-12. Basidiospores of species in the Nidulariaceae from Illinois. Scale line equals 30 µm. 8. Nidularia pulvinata. 9. Cyathus stercoreus. 10. Cyathus olla. 11. Crucibulum laeve. 12. Cyathus striatus.

Cyathus olla Batch ex Pers. Figs. 4, 10, 15

Basidiocarps 6-11 mm tall (excluding emplacement), 3-11 mm broad at the apex; funnelform, flaring out widely in the upper third, constricted slightly in the lower third. Outer peridial surface grey to brown ("buffy brown" to "smoke grey", rarely "wood brown"); occasionally with scattered hairs. Inner peridial surface grey ("olive grey" to "smoke grey"), often concolorous with the outer peridial wall; shiny; lacking striations or plications. Margin of mouth glabrous. Epiphragm lacking in specimens examined from Illinois (but tomentose and concolorous with the outer peridial wall in extralimital California material--Sundberg 1365).

Peridioles few; 2-3 mm long and broad; irregularly rhomboid; dark grey to black; funiculus present, attached to peridial wall.

Basidiospores 9.0-16.5 x 6.0-9.0 µm; moderately thick-walled; ovate to dacryoid, occasionally apiculate; hyaline; smooth.

Habit and habitat: Scattered to gregarious on compost, twigs, and refuse. Late June to October.

Material examined: Cook Co.: Chamberlain sn (F 1151266). DuPage Co.: Moffatt 1238 (F 1229050); and Harper sn (F 1322762). Knox Co.: Wujeck 191 (DSW).

Moffatt (1923) previously reported this species from Illinois (county not noted) as C. vernicosus (Bull.) DC, an epithet now known to be synonymous with C. olla (Brodie 1975).

Cyathus olla can be differentiated by the large size and distinctly flaring mouth of its smooth (non-plicate) peridium, and by its large peridioles.

Cyathus stercoreus (Schw.) de Toni Figs. 5, 9, 16

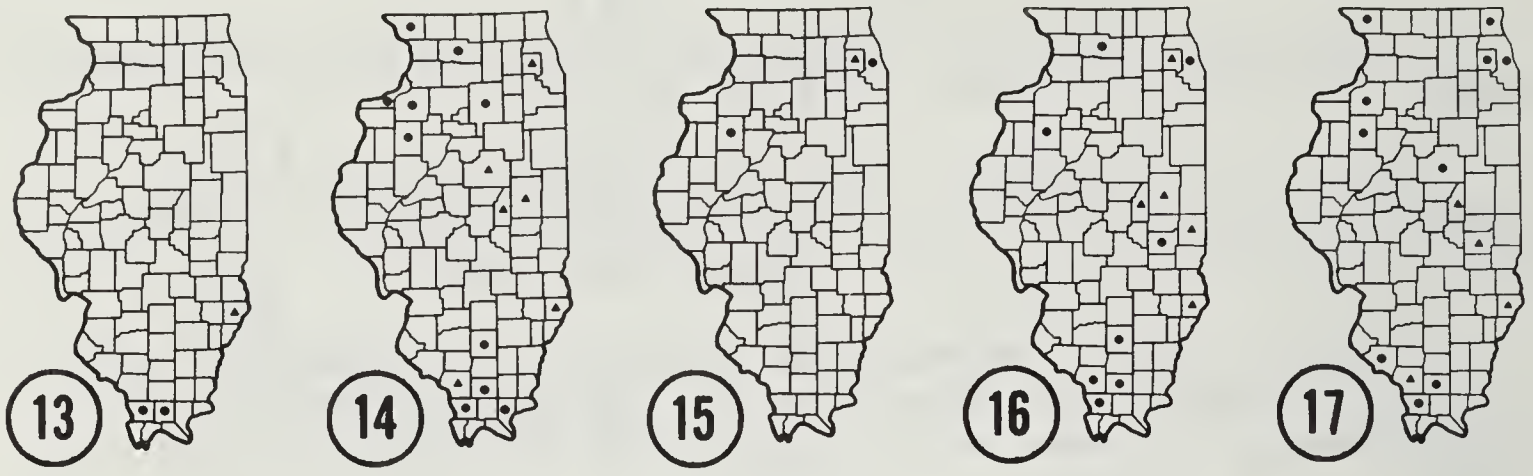
Basidiocarps 2-11 mm tall (excluding emplacements), 3-8 mm broad at the apex; funnelform, with upper edge often outwardly flaring, slightly constricted in the lower third. Outer peridial surface light to medium brown ("wood brown" to "tilleul buff", occasionally to "light grey"); often with large, scaly, concolorous hairs in young specimens, becoming glabrous with age. Inner peridial surface grey ("light gull grey" to "dark gull grey"), often with a silvery sheen; smooth and shiny; lacking striations. Margin of mouth glabrous. Epiphragm buff ("cartridge buff") and slightly tomentose when present.

Peridioles several; 2-3 mm long and broad; irregularly ovoid; dark grey ("deep neutral grey" to "dark neutral grey"); funiculus present, upper peridioles often free, but lower ones attached to the peridial wall.

Basidiospores (18-)19.5-37.5(-54.0) x (13.5-)18-34.8 (-52.5) µm; globose to ovoid; thick-walled; hyaline.

Habit and habitat: Gregarious, often in large numbers; usually coprophilous or on cultivated manured soil (one specimen, Whiteside sn, appeared to be on hay). Early June to early October.

Material examined: Coles Co.: Whiteside sn (EIU). Cook Co.: Sella sn (F, no number). DuPage Co.: Moffatt 70 (F 1229091), 1459 (F 1229485). Jackson Co.: Bankson and Mohlenbrock sn; Burton 128; Sundberg 2317; Wujek 82. Jefferson Co.: Waite 33. Knox Co.: Wujek 146 (DSW). Ogle Co.: Moffatt 1192 (F 1229018--a mixed collection). Union



Figs. 13-17. Distribution of the Nidulariaceae in Illinois. Circles (●) represent new records reported herein, triangles (▲) indicate previously known distribution points. 13. Nidularia pulvinata. 14. Crucibulum laeve. 15. Cyathus olla. 16. Cyathus stercoreus. 17. Cyathus striatus.

Co.: Bloom 7. Williamson Co.: Erickson 7, Guerke sn.

This species has also been noted from Champaign (Coker and Couch 1928), DuPage (Moffatt 1923), Edgar (Parker 1975), Lawrence (Parker 1975), and Piatt (Parker 1975) counties.

Cyathus stercoreus can be readily distinguished from the other species by its funnel-like shape, coprophilous habitat, and very large basidiospores.

Cyathus striatus Huds. ex Pers. Figs. 6, 12, 17

Basidiocarps 4-20 mm tall (excluding emplacement), 1-10 mm broad at the apex; elongate-bell-shaped, often strongly constricted in the lower third. Outer peridial surface cinnamon to dark brown ("ochraceous-tawny" to "buckthorn brown", occasionally "argus brown" to "brussels brown", rarely "tawny olive"); plicate; with abundant scattered rough hairs. Inner surface buff to grey ("pale ochraceous-buff" to "light buff"); with plicate striations extending about halfway down the wall, otherwise smooth. Mouth setate; setae reddish brown ("russet" to "tawny"). Epiphragm white and smooth when present.

Peridioles few; 2-3 mm long and broad; irregularly ovoid; grey ("slate grey"); funiculus present, attached to the peridial wall.

Basidiospores (9.5-)12.5-24.0(-25.4) x 6.9-15.0 µm; elliptic to ovoid (rarely centrally constricted); smooth; rather thick-walled; hyaline.

Habit and habitat: Scattered to gregarious on dead hardwood and decaying leaves. Early July to late October.

Material examined: Cook Co.: Chamberlain sn (F 1150807); Edgecombe sn (F nos. 1205952, 1201864, 1201871, 1207891); Harper sn (F nos. 523997, 1322764, 1322771); Moffatt sn (F 1229047). DuPage Co.: Moffatt 326 (F 1229054), 371 (F 1229073), 1214 (F 1229032), 1418 (F 1229096), 1488 (F 1229048), sn (F 1229025, F 1229093). Henry Co.: Harper sn (F nos. 1322765, 1323027, the latter is a mixed collection). Jackson Co.: Bankson and Gilman 165; Halbrendt 9; Parady 2, 7, 9, 10; Sundberg 2077. Jo Daviess Co.: Ozmont and DeFillips 0063, 0085. Knox Co.: Wujek 355 (DSW). Lake Co.: Steyermark 67081 (F 1301561). McLean Co.: Dey 8259 (JPD). Randolph Co.: Cochrane sn. Union Co.: Sundberg 2096; West 952. Williamson Co.: Koslawski 15.

In addition to reports (counties not noted) by Murrill (1911) and Moffatt (1923), C. striatus was previously noted from Coles (Parker 1975), Jackson (Bankson and Gilman 1963), Lawrence (Parker 1975), and Piatt (Cooke 1965, Parker 1975) counties.

Cyathus striatus can be readily distinguished from the other species included herein by its striate (plicate) peridium and fimbriate mouth.

ACKNOWLEDGEMENTS

We wish to acknowledge Dr. J. P. Dey, Illinois Wesleyan University, Dr. P. Ponce de Leon, Chicago Field Museum of Natural History, Dr. W. Whiteside, Eastern Illinois University, and Mr. D. S. Wujek, Carl Sandburg College, for the loan of specimens in their care. Also, we wish to express our appreciation to Mr. J. Richardson, Scientific Photography and Illustration Facility, Southern Illinois University, for his technical advice and assistance.

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HOMING OF GREEN SUNFISH (LEPOMIS CYANELLUS) IN A WEST-CENTRAL ILLINOIS STREAM

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ABSTRACT: The homing behavior of green sunfish (Lepomis cyanellus) was studied in two 110-m sections of Williams Creek, separated by a 30-m section of ford and riffles. All fish were captured by electrofishing, tagged with numbered plastic jawbands, measured and released. Fish were initially released where captured but later were displaced either upstream or downstream to distances of 10-120 m. Green sunfish returned to home areas approximately 2 m long following displacements of up to 80 m upstream or 90 m downstream from their original capture points. Percent recapture within this home area did not appear to depend on the distance of displacement; however, the degree and accuracy of homing appeared to depend on habitat in the vicinity of the home area. Visual mechanisms were probably used in homing. The shallow riffles and ford did not affect homing. A larger number of longer fish homed than shorter fish. Fish returned home within seven days after displacement, although the time it took them to return did not appear to depend on displacement distance.

INTRODUCTION

The objectives of this study were to determine if homing was exhibited by green sunfish (Lepomis cyanellus) in a stream and to determine the relationship between homing and total lengths of the fish.

Homing has been defined by several authors; however, Gerking (1959) defined homing as "the choice that a fish makes between returning to a place formerly occupied instead of equally probable places." This definition is used in this study. To differentiate homing from home range, Gunning (1963) defined the latter as "the area over which an animal normally travels."

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*Address correspondence

Hasler and Wisby (1958) found that both sexes of green sunfish returned to an 11 m by 40 m area in a pond, with some males returning to their nests. In addition, green sunfish moved to deeper water in winter and returned to their original capture sites the next spring. When some fish were displaced in their own pond, they returned almost directly and immediately to their capture sites, but when displaced to another pond they swam "aimlessly." Gunning (1959) found that longear sunfish (Lepomis megalotis) returned to their home areas following displacements of 61 m and 107 m from their original capture points. Larimore (1952) found that smallmouth bass (Micropterus dolomieui) returned to their home pools (sizes unspecified) after displacements of 225 m upstream and 1304 m downstream, with a tendency to overshoot in a few cases. Bass with total lengths of 23 cm or less tended to stray more than larger ones. In addition, he displaced some longear sunfish and found that a few of these fish returned to their home pools following displacements of 225 and 1062 m.

MATERIALS AND METHODS

The study was conducted from April 1 to August 24, 1971 in Williams Creek, Schuyler County (T3N, R4W, Section 4). The study area consisted of two 110-m sections, having a sand and gravel bottom, separated by a 30-m ford and riffles. Markers were placed at 10-m intervals in each of the 110-m sections as landmarks to locate positions of the fish. Numerous tree stumps and fallen logs provided excellent habitat for green sunfish, and most of the study area except the ford was shaded.

All fish used in the study were captured with a portable electroshocker. Shocking was begun at the farthest marker downstream and proceded upstream to the end of the study area. Each area was shocked until no more green sunfish were captured. Before being handled, each fish was allowed to recover from the stunning effect either in the electrode webbing or a holding net. Each fish was tagged with a numbered plastic jawband, measured to the nearest mm, and placed in a pail or holding net. Jawbands were placed on the dentary as posteriorly as possible so that oral activity might be least affected. The tag number, total length of the fish, natural recognizable deformities or those caused by the tagging procedure, and location of capture were recorded. Some previously tagged fish were remeasured at approximately monthly intervals and additional damage, if any, caused by the tag was noted.

It was necessary to initially determine whether or not green sunfish remained within a restricted area after capture, tagging and replacing them where caught. Thus, during April,

74 fish were tagged and released where caught. Later when fish were displaced they were carried in closed styrofoam pails, containing about 3 liters of water, to a point upstream or downstream. Fish were transported only through stream sections that were just shocked or overland. The initial displacement distance was chosen at 10 m, but thereafter those fish recaptured and others were displaced farther. Some fish were displaced and released so that they had to cross a ford to return to their original capture points. Groups of 1-12 fish were transported at a time, but they were released individually or in groups of 2 or 3.

Some fish were displaced before they had returned to their original points of capture. This was nearly unavoidable because time considerations in the field precluded the examination of the recapture history of every fish. This could have lessened the reported recapture percentages.

From May through August, 270 fish were tagged and most were displaced, being treated similarly to fish captured and released in April.

To determine if total length of the fish affected homing performance, fish were placed in four length groups of 8.1 cm or less, 8.2-12.2 cm, 12.3-15.2 cm and 15.3 cm or more. These length groups approximated age groups (Andersen, 1972).

RESULTS

Of the 74 fish tagged and released at their capture sites during April, 54 were captured. Of these, 44 (59.4%) were recaptured 2 or more times within 0-10 m of their original capture sites and of these 44, 43 were recaptured within 0-2 m (Table 1). Seventeen were captured 4 or more times within 0-10 m, while 14 were captured 4 or more times within 0-2 m of their original capture sites.

TABLE 1. Number and Percentages of Non-displaced and Displaced Fish Captured Two or More Times Within Selected Intervals.

	Non-displaced Fish Captured		Displaced Fish Captured	
Interval (m)	Number	Percent*	Number	Percent**
0-2	43	58.1	78	28.9
0-10	44	59.4	106	39.3
11-20	1	1.4	15	5.5
21-30	5	6.7	17	6.3
31-40	0	0	8	3.0
41-50	1	1.4	4	1.5
50+	3	4.1	36	13.3

* based on 74 fish.
** based on 270 fish.

Of 270 fish tagged from May to August, 186 were recaptured (Table 1). Of these, 106 were captured two or more times within 0-10 m and 78 of these 106 were recaptured within 0-2 m.

The percentages of recapture of displaced fish within 0-2 m intervals of the original capture points did not appear to be dependent upon the distance of displacement. Most of the fish displaced upstream were recaptured when displaced 10, 40, and 60 m. Percentages of total recaptures for these fish were 32.3, 15.4, and 20.0%, respectively. Most of the fish displaced downstream were recaptured when displaced 10, 20, 60, 80 and 90 m. Percentages of the total recaptures for these were 5.5, 36.4, 37.5, 37.5 and 7.1%, respectively.

Larger percentages of fish were recaptured within 0-10 m intervals of their original capture points (many of these actually within a 0-2 m interval) following upstream displacements of 10, 30, 40, 60 and 70 m. For these five upstream displacement distances, the following percentages were found within this 0-2 m interval: 32.3 (11 of 34), 25.0 (1 of 4), 15.4 (2 of 13), 20.0 (2 of 10), and 12.5 (1 of 8)%, respectively

Relative to other intervals, larger percentages of fish were recaptured within 6-10 m intervals of their original capture points following downstream displacements of 10, 20, 30, 60 and 80 m, and as was the case in upstream displacements, many of these were within a 0-2 m interval of their original capture points. For these five downstream displacement distance the following percentages were found within the 0-2 m interval: 3.3 (1 of 30), 30.8 (8 of 26), 25.0 (1 of 4), 26.1 (12 of 46) and 27.3 (6 of 22)%, respectively.

Concentrations of recaptures within specified distances, which were at least 50% greater than recaptures in adjacent 5-m intervals, will be termed clusters. Clusters were within the intervals of 0-5, 26-30, 56-60 and 100+ m from the original points of capture. The clustering effect was even more evident when displacement distances were disregarded and the number of recaptures were considered together. For example, the first cluster (76 recaptures) was in the 0-5 m interval and represente 22.7% and 32.3% of the total displacements and total recaptures, respectively. The other three intervals showing clusters had less than 10% of the fish displaced. In addition, 49 of the 76 recaptures in the first cluster were taken within a 0-2 m interval of their original capture points.

The number of fish recaptured following upstream and downstream displacements were 52 of 73 (Table 2) and 90 of 136 (Table 2), respectively. The total number of displacements and recaptures were 96 of 137 and 139 of 197, respectively. The percentages of fish recaptured were 71.2 and 66.2, respectively,

and percentages of displacement recaptures were 70.1 and 70.6, respectively. A simple test of proportions was used to determine that there was no statistical difference between upstream and downstream displacement recapture and fish recapture percentages (Chi-square value less than 1.0).

A change in percent of recapture occurred during the study, as there was a decrease of 5.4% in May and an increase of 2.7% in June-July. June and July were considered together since in June the study area was shocked only one time due to heavy rains which prevented work for most of the month. The percentage decreased 3.2% in August. An overall decrease of 5.9% was observed during the entire study period.

Numbers of fish tagged and recaptured for the four length groups (approximating ages) were 152 and 117, 92 and 52, 20 and 13, and 2 and 0, respectively. Most of these were captured two or more times within 0-10 m intervals (Table 4), usually within 0-2 m intervals. Fewer fish were found within other intervals. Each length group exhibited clustering. Group 1 showed clustering within 0-5, 26-30, 91-95, and 100+ intervals with 43, 13, 2 and 15 recaptures, respectively. Group 2 showed clustering within 0-5, 11-15, 26-30, 46-50, 56-60, and 100+ intervals with 20, 8, 9, 4, 5 and 6 recaptures, respectively. Group 3 showed clustering with 0-5, 31-35, 46-50, and 61-65 m intervals with 9, 3, 1 and 2 recaptures, respectively. Each length group showed clustering within 0-2 m intervals with 54, 16 and 6 recaptures, respectively.

The cumulative percentages of the total recaptures for the first three length groups (none recaptured in 4th group) showed that group 3 had the highest percentage of recapture within 15 m of the original capture points (47.4%) while group 2 had the highest percentage with 30-m distances (63.4%) (Table 5).

DISCUSSION

When green sunfish were captured, tagged and released at their capture points, or displaced, most of them remained or returned within 2-m intervals. This indicated that most green sunfish occupied a home area approximately 2 m in length. No other work was found which reported the size of the home area of the green sunfish. However, Gerking (1953) used a similar procedure to determine the home range of fin-clipped green and longear sunfish, but stated that green sunfish were too scarce in the study areas to make positive judgments concerning the home range. He obtained recapture information for green sunfish over a one-summer period which paralleled that for longear sunfish observed for a 4-year period. The home range of the green sunfish was therefore thought to be 30-61 m in length, the same as for the longear sunfish.

TABLE 2. Recaptures of Fish Displaced Upstream for Distances of 10-110 Meters.

Distance Displaced (m)	Total Number of Fish Displaced	Fish Recaptures		Total Number of Displacements	Displacement Recapture	
		Number	Percentage		Number	Percentage
10	26	20	27.4	43	34	24.8
20	4	-	-	10	3	2.2
30	6	4	5.5	8	4	2.9
40	9	4	5.5	20	13	9.5
50	15	15	20.5	18	18	13.1
60	7	4	6.8	17	10	7.3
70	2	2	2.7	11	8	5.8
80	2	2	2.7	4	3	2.2
90	1	-	-	3	2	1.4
100	-	-	-	2	1	0.7
110	1	-	-	1	-	-
Totals	73	52	71.2	137	96	70.0

TABLE 3. Recaptures of Fish Displaced Downstream for Distances of 10-120 Meters.

Distance Displaced (m)	Total Number of Fish Displaced	Fish Recaptures		Total Number of Displacements	Displacement Recapture	
		Number	Percentage		Number	Percentage
10	22	12	8.8	30	18	9.1
20	24	12	8.8	26	22	11.2
30	3	3	2.2	4	4	2.0
40	-	-	-	2	1	0.5
50	1	1	0.7	2	2	1.0
60	30	21	15.4	46	32	16.2
80	17	13	9.6	22	16	8.1
90	25	18	13.2	43	28	14.2
100	6	5	3.7	11	9	4.6
110	5	3	2.2	7	5	2.5
120	3	2	1.5	4	2	1.0

TABLE 4. Number of Fish in Each Total Length Group Captured Two or More Times after April Within Selected Intervals.

Interval (m)	Group I ≤ 8.1 cm		Group II 8.2-12.2 cm		Group III 12.3-15.2 cm	
	Number	Percentage*	Number	Percentage	Number	Percentage
0- 2	54	20.3	16	6.0	6	2.3
0-10	71	26.7	25	9.4	7	2.6
11-20	6	2.3	6	2.3	2	7.5
21-30	13	4.9	4	1.5	-	-
31-40	6	2.3	1	0.4	1	0.4
41-50	3	1.1	1	0.4	-	-
50+	18	6.8	15	5.6	3	1.1

*Based on 266 fish.

TABLE 5. Cumulative Percentages of the Total Recaptures for Three Total Length Groups Within Specified Distances, Following Upstream and Downstream Displacements of 10-120 Meters.

Specified Distance (m)	Group I*	Group II**	Group III***
15	40.0	43.7	47.4
30	58.5	63.4	57.9
45	71.8	69.0	78.9
60	82.2	83.1	89.5
75	87.4	85.9	100.0
90	87.4	88.7	100.0
100+	100.0	100.0	100.0

*Based on 135 recaptures.
**Based on 71 recaptures.
***Based on 19 recaptures.

The physical features of the study area were important in homing performance of green sunfish. Most of the logs and stumps in the study area were from 26-30 m apart. This, plus the data concerning the intervals where clusters were found, indicated that most fish were recaptured at stumps or logs following displacements. When displaced, fish which were recaptured apparently took one of four courses of action: 1) returned to their home logs, 2) returned to a log between the home log and the release point, 3) travelled to and remained at a log past the release point, or 4) overshot the home log to some other. The size of each cluster indicated that most fish apparently took the first course, with progressively fewer taking the others.

The shallow riffles and ford did not prevent green sunfish from returning to their home areas. Many fish apparently returned through riffle

and ford depths of 3-10 cm during periods of low water. Gunning (1959) found that pools and riffles were not barriers to homing longear sunfish. Larimore (1952) found that riffles 5 cm or less deep did, however, act as barriers to homing smallmouth bass.

Shocking was usually done every 2-3 days and most fish returned to their home areas did so within 7 days. Many had already returned by the time of next shocking after displacement. The time period required for a fish to home did not appear dependent on displacement distance. Gunning (1959) stated that some longear sunfish had returned to their home ranges within 24 hrs. following upstream and downstream displacements. Larimore (1952) reported that some smallmouth bass had returned to their home pools within seven days following upstream and downstream displacements.

Although sensory mechanisms used in homing of green sunfish were not determined in the present study, the precision of homing indicated that vision was responsible. Had olfaction been the primary sense used, recaptures of fish displaced downstream would probably have been higher than those displaced upstream. No statistical difference was found in upstream vs. downstream recaptures. However, Gunning (1959) found that olfactory mechanisms were responsible for longear sunfish returning to their home ranges in a stream.

Considering length groups of green sunfish which approximate age groups, a greater percentage of fish in the 12.3-15.2 cm grou homed than did those in the two shorter length groups. It is possible that these larger fish were more territorial and were returning to defend their territory, or it may be that they had more experience and learning time in the study area than younger (shorter) fish. Larimore (1952) found that smallmouth bass 23 cm or less did not home as well as those of greater lengths.

There was some change in composition in the population of green sunfish in the study areas as indicated by the change in the cumulative percentages of recaptured fish. The largest numbers of fish were tagged following flooding caused by rains, indicated that it could have influenced changes in the populatio In the June-July interval, an increase in percentage of recapture fish indicated that more fish probably remained in the study area It is possible that these fish were engaged in reproductive activities, since they breed in midsummer (Fritz, 1964). However, considering that half of the fish used in this study were tagged in this interval, the cumulative percentage perhaps should have increased more than the observed 2.7%. During May and August, a decrease in the cumulative percentage of fish recaptured may have indicated that there was movement in and out of the study area, which may have been caused by competition, mortality, or experimental treatment. However, concerning mortality due to

experimental treatment, this was probably limited since fish were recaptured several times throughout the study with little or no inflamation near the tags. Less than 3% of the total recaptured fish suffered jaw deformities as a result of tagging. But, some smaller fish which were tagged seemed to lose weight even though weights were not recorded; larger fish seemed unaffected.

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A COMPARISON OF WETLAND BIRD AGGREGATIONS AND MACROBENTHOS IN TEMPORARY SPRING PONDS

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ABSTRACT

Censuses of migrating wetland birds in two temporary ponds in northeastern Illinois were made from 18 March to 1 June 1974. The shallower pond had the highest mean number of species (3.96 versus 3.09), and mean number of individuals (34.6 versus 7.8), but the Shannon-Wiener index of species diversity showed little difference. The Mallard was the most important species at both ponds, based on frequency and numbers present throughout the study. The two bird aggregations had a coefficient of community of 0.48, indicationg a low similarity. Benthos biomass was greatest in the deep pond, but its greater depth seemed to render them less available to all species of feeding birds.

INTRODUCTION

Temporary spring ponds resulting from snow melt and rains are relatively common in the north central states. Shaw and Fredine (1956) inventoried a total of 1.42 million hectares (3.5 million acres) in the north half of the Mississippi Flyway. These temporary ponds consist of two wetland types, (1) seasonally flooded basins or flats, and (2) inland fresh meadows. Due to their temporary nature, they are most important for migrating birds, not local breeders.

The distribution of the essential habitat requirements in the ponds determines the density and types of birds that use them. The importance of invertebrates for shorebirds, rails and similar species is well known as they consume large quantities of invertebrates (Bent 1927, 1929, Martin et al. 1951). Recently it has been found that aquatic invertebrates comprise a major portion of the food of breeding waterfowl (Swanson and Meyer 1973, Krapu 1974a, 1974b, Swanson and Serie 1974). Schroder (1973) summarized the available literature and stated that "egg-laying hens ...

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require an increased protein level in their diet which is obtained via invertebrate consumption." Keeping in mind these facts, the basic objective of this study was to compare wetland bird aggregations using two closely situated but different temporary ponds, and explore the bird-invertebrate relationship.

STUDY AREA

The deep pond, a type 2 wetland, and the shallow pond, a type 1 wetland, were located in northwestern Cook County, Illinois, just southwest of Barrington Hills. The deep pond was artificially created over 10 years ago. During the period of study, it had a depth ranging between 0.5 and 1.5 m, with a surface area of 1.3 ha. The shallow pond, a flooded flat, was naturally occurring and only 0.1 to 0.5 m deep, with 1.7 ha of surface area. Both ponds were located so that their closest points were only 100 m apart. By mid-July the shallow pond was nearly dry, but the deep pond remained until nearly mid-September.

Broadleaf cattail (Typha latifolia), river bulrush (Scirpus fluviatilis), and muhly grass (Muhlenbergia Mexicana) dominated the vegetation of the deep pond. Most of the shallow pond's bottom was unvegetated, except for a 900 m^2 area of beaked sedge (Carex rostrata) plus a few scattered individuals of water plantain (Alisma plantago-aquatica). A combination of large-seeded smartweeds (Polygonum pensylvanicum), Canada goldenrod (Solidago canadensis), plus several species of grasses, including creeping bentgrass (Agrostis palustris), dominated the surrounding old field vegetation.

METHODS AND MATERIALS

Wetland bird species of the orders Podicipediformes, Ciconiiformes, Anseriformes, Gruiformes, and Charadriiformes (American Ornithologists' Union 1957), were censused from 18 March to 1 June 1974, by two investigators using binoculars and a spotting scope. The same census route was walked each period. The ponds were located close enough together (100 m) so that double counts were prevented. Most surveys were made in the afternoon at 1630 hours, with four being made in the morning at 0830 hours. Each lasted about one hour.

An importance value (IV) for each bird species was determine by summing the relative frequency for the species (the number of census periods the bird was observed in, divided by the total number of census periods), and the relative density (the total number of individuals of a species divided by the total number of individuals for all species at the pond). This assumes that frequency and density are equally important. An IV of 200% was possible. A comparison of the similarity between bird aggregations was made by calculating a coefficient of community. $C = 2W / (A + B)$, where W is the sum of the lesser of the two IV's for each of all species shared by the two aggregations. A is the total IV for the shallow pond, and B is the total IV for the deep pond. A range of 0-1 is possible for C, with 1 indicating the greatest similarity (i.e. identical associations).

The Shannon-Wiener Index (Margalef 1958) was used to assess species diversity of birds by ponds and census periods. This particular index was chosen because of its less inherent sensitivity to sample size, compared to other commonly used indices (Kricker 1973). The index is $\underline{H'} = \Sigma p_i \log_e p_i$, where p_i is the proportion of individuals of species i based on the total number of individuals present for all species. $\underline{H'}$ values were calculated according to procedures set forth by Lloyd et al. (1968). In the equation for $\underline{H'}$, absolute numbers of birds, as collected in the field were used.

Benthic samples were obtained randomly, by using an Ekman dredge (15.2 x 15.2 cm opening) in depths less than 1.0 m, the depth normally available to feeding ducks. Each sample was placed in a large plastic bag with ethanol. Samples were hand sorted, identified (Pennak 1953), stored in ethanol, and later weighed. The total process was completed over a four month period, with reported weights being minimums due to dehydration. Wet weights are reported here, and can be converted to approximate dry weights by dividing by 10 (Moyle 1961). Only macrobenthos retained by a No. 12 U.S. Standard Seive, approximately 1 mm^2 opening, were considered in this study.

RESULTS

Macrobenthos: Eight and six taxa of benthos were identified in the deep pond and the shallow pond, respectively. The deep pond had a slightly greater mean number per m^2 than did the shallow pond, with 486.3 versus 417.7. Mean biomass was nearly twice as high in the deep pond (19.85 g/m^2) as in the shallow pond (10.04 g/m^2). Numbers per square meter in the deep pond were 291, 285, and 882, while in the shallow pond they were 780, 137, and 344, respectively for 5, 11, and 25 April. Biomass in g/m^2 were 6.2, 9.3, and 44.1 in the deep pond, and 20.0, 1.3, and 8.8 for the shallow pond for the same respective dates. Collected taxa included Hirundinea, Decapoda, Limnephilidae, Coptomus, Dytiscus, Physa, Lymnaea, Gyraulus, and Musculium. Physa was the most common in both number per square meter and biomass per square meter, in both ponds.

Birds: The greatest numbers of birds occurred between 6 and 25 April at the deep pond (Table 1) while the greatest numbers at the shallow pond were present from 19 March to 18 April and 2 to 17 May (Table 2). Totals of 797 and 179 individuals were counted at the shallow pond and deep pond, respectively. Mallard (Anas platyrhynchos), Blue-winged Teal (Anas discors), Northern Shoveler (Anas clypeata), American Coot (Fulica americana), Killdeer (Charadrius vociferus), and Common Snipe (Capella gallinago) were the only species common to both ponds. A total of 23 species were observed at both ponds, inclusively.

Mallard was the most abundant species observed, at both ponds (Tables 1 and 2), and had the highest importance (Table 3). American Coot was second in importance to Mallard at the deep pond, but the Blue-winged Teal held that rank at the shallow pond. Other species with high IV's at the deep pond included Blue-winged Teal, Sora (Porzana

TABLE 1. Numbers of individuals and species diversity of wetland birds observed using the deep pond.

SPECIES	NUMBER PRESENT																																		
	March						April									May														June						Total
	18	19	21	23	27	29	5	6	8	11	15	18	22	25	29	2	4	7	10	17	21	29	1												
Pied-billed Grebe								1	1					1																					3
American Bittern											1																								1
Mallard	13	2	4	4			4	4			3	4		5	2	1	3	1	1		3		1												55
Blue-winged Teal								3	6	1	7	3		2		2			2																26
Northern Shoveler								1	5																										6
Virginia Rail													1				2	2	1		2		1												9
Sora											3		2	5	4	2	1	1	1	1															20
American Coot							2	2	2	1	3	2	2	4	1	2	2	2		2	3	2	2													34
Killdeer									1			1		2							3														7
Common Snipe								3	2		2	8	1	2																					18
TOTAL	13	2	4	4	0	0	6	14	17	2	19	18	6	21	7	7	8	6	5	3	11	2	4												179
TOTAL NO. SPECIES	1	1	1	1	0	0	2	6	6	2	6	5	4	7	3	4	4	4	4	2	4	1	3												
H'	0	0	0	0	-	-	.28	.73	.68	.30	.71	.61	.58	.84	.42	.59	.75	.58	.58	.28	.60	.30	.45													

MEANS: H'=.44 Species/Day=3.09 Individuals/Day=7.78

SPECIES	NUMBER PRESENT																									
	March				April											May								June		
	18	19	21	23	27	29	5	6	8	11	15	18	22	25	29	2	4	7	10	17	21	29	1	Total
Horned Grebe							1	1																2
Canada Goose								2	2															4
Mallard		47	79		30	20	16	15	12		8	3			2	2	2	3			1			239
Black Duck		5			2																			7
Pintail		2			5	10																		17
Green-winged Teal											2													2
Blue-winged Teal		3	3		5	25	38	10	16		33	25			4	10	10	2	6	7	3		5	205
American Wigeon		1		5	14	47		35	2															104
Northern Shoveler					2		1		4															7
Redhead			11						28															39
Ring-necked Duck		8	2																					10
Canvasback			2																					2
American Coot		1																						1
Semipalmated Plover												24							2	14				40
Killdeer		2	2	2	1	12	6	2	3	3	2	3	2	4		4	4	2	1	1	3	3	3	2	67
Common Snipe						2	1				1	5					3				10				22
Greater Yellowlegs																		24	2	1					27
Lesser Yellowlegs																	1								1
Short-billed Dowitcher													1												1
TOTAL		3	67	99	6	72	109	58	66	67	3	51	55	4	0	10	20	38	8	10	34	7	3	7	797
TOTAL NO. SPECIES		2	7	6	2	8	6	5	6	7	2	5	5	1	0	3	5	4	4	4	4	3	1	2	
H'		.28	.48	.33	.18	.72	.62	.38	.55	.66	.24	.47	.46	0	-	.46	.58	.41	.65	.47	.55	.44	0	.26	

NEANS: H'=.42 Species/Day=3.96 Individuals/Day=34.65

TABLE 3. Importance values of wetland birds using both ponds.*

SPECIES	DEEP POND					SHALLOW POND				
	F	D	RF	RD	IV	F	D	RF	RD	IV
Horned Grebe						.087	2	2.15	.25	2.40
Pied-billed Grebe	.130	3	4.21	1.68	5.89					
American Bittern	.043	1	1.39	.56	1.95					
Canada Goose						.087	4	2.15	.50	2.65
Mallard	.696	55	22.55	30.73	53.28	.609	239	15.09	29.99	45.08
Black Duck						.087	7	2.15	.88	3.03
Pintail						.130	17	3.22	2.13	5.35
Green-winged Teal						.043	2	1.06	.25	1.31
Blue-winged Teal	.348	26	11.27	14.52	25.79	.739	205	18.31	25.72	44.03
American Wigeon						.261	104	6.46	13.05	19.51
Northern Shoveler	.087	6	2.82	3.35	6.17	.130	7	3.22	.88	4.10
Redhead						.087	39	2.15	4.89	7.04
Ring-necked Duck						.087	10	2.15	1.25	3.40
Canvasback						.043	2	1.06	.25	1.31
Virginia Rail	.261	9	8.45	5.03	13.48					
Sora	.391	20	12.67	11.17	23.48					
American Coot	.696	34	22.55	18.99	41.54	.043	1	1.06	.13	1.19
Semipalmated Plover						.130	40	3.22	5.02	8.24
Killdeer	.174	7	5.64	3.91	9.55	.956	67	23.88	8.40	32.08
Common Snipe	.261	18	8.45	10.06	18.51	.304	22	7.53	2.76	10.29
Greater Yellowlegs						.130	27	3.22	3.39	6.61
Lesser Yellowlegs						.043	1	1.06	.13	1.19
Short-billed Dowitcher						.043	1	1.06	.13	1.19
TOTAL	3.087	179	100.00	100.00	200.00	4.039	797	100.00	100.00	200.00

*Column Headings F = Frequency RF = Relative Frequency IV = Importance Value
D = Density RD = Relative Density

carolina), and Common Snipe, while Killdeer, and American Wigeon (Anas americana) were of high importance at the shallow pond (Table 3). The two wetland bird aggregations had a coefficient of community of 0.48, indicating a relatively low level of similarity. H' values (Tables 1 and 2) ranged from a low of 0, for both ponds, to highs of 0.84 and 0.72 at the deep and shallow ponds, respectively. Mean values were 0.44 (deep pond) and 0.42 (shallow pond), indicating that both aggregations were similar in diversity. Diversity was higher early in the season at the shallow pond, but at the deep pond, diversity did not become high until 5 April.

DISCUSSION

The two ponds represent wetland communities which provide habitat requirements for the different wetland bird aggregations. The deep pond with its greater depth and duration of surface water, supported a typical emergent herbaceous marsh. Birds frequenting it that use heavy cover include the American Bittern (Botaurus lentiginosus), Virginia Rail (Rallus limicola), Sora, and American Coot. Contrasting with the deep pond was the shallow pond which contained only a minimal amount of emergent aquatic plants. Its shallow depth and accompanying exposed mud flats provided condidtions which were near optimal for feeding shorebirds and waterfowl.

Even though macrobenthos were present in slightly greater numbers in the shallow pond, biomass was nearly twice as high in the deep pond. This difference may be explained by two factors. First, the deep pond provided a more constant habitat for the macrobenthos throughout April,whereas the shallow pond's water levels fluctuated greatly, as would most ponds with similar dimensions. Published data supporting this conclusion indicate that permanent ponds and lakes normally have more abundant and diverse benthic faunas. In separate studies of Minnesota lakes, Hooper(1951) found approximately 680 individuals per m^2 in a single seepage lake during the summer, while Wilson (1958) found a mean of 7299 individuals per m^2 in several permanent lakes during April. Dineen (1953), studying, a permanent but shallow pond, found only 261 individuals per m^2 in April. In two different (temporary) green-tree reservoirs in New York and southern Illinois, Krull (1969) and Hubert and Krull (1973) found numbers of invertebrates (not just benthos) similar to ours.

Second, the greater abundance of aquatic submergent plants in the deep pond provided more substrates for invertebrates. Many workers have recognized the aquatic plant-invertebrate relationship (e.g. Krecker 1939, Berg 1949, McGaha 1952, Moyle 1961, Krull, 1970), but Moyle (1961) was one of the earliest to point out the implication of the relationship for waterfowl. But these more abundant invertebrates were largely unavailable to the samller shore birds feeding at the deep pond.

The Shannon-Wiener index did not show any significant difference between the two aggregations. This may be explained by the fact that invertebrates were less available in the shallow pond, but the large number of plant seeds (collected the dredge) readily available in the shallow pond for

the birds, may have tended to counteract the lack of benthos. Thus, attracting enough birds to even up the total use of the ponds.

The importance of these two particular ponds for wetland birds is relatively low, but they represent the abundant temporary wetlands in the northcentral states, which are important collectively. Efforts should be made to conserve such wetlands and enhance their potential for invertebrate production. More research should be done to document the benthos present in all regions of the country which occur in temporary and permanent ponds.

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OBSERVATIONS OF NESTING MISSISSIPPI KITES IN SOUTHERN ILLINOIS

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Mississippi kites, endangered in the state, were studied in Union County, Illinois. Thirteen pairs of adults and five nests were located; adult kites appeared pair-bonded when arriving at the breeding area. Incubation began in late May and eggs hatched in late June and early July. Nests were located near openings in woodlots of at least 80 ha, and generally contained a single egg. Four nestlings were banded and all fledged by 13 August. Fledglings hunted and continued to be fed by adults until all kites left the breeding area in early September. Kites fed mainly on insects captured over open fields and forested areas.

INTRODUCTION

Mississippi kites (Ictinia mississippiensis) were common in southern Illinois during the late 1800's (Nelson, 1877; Ridgway, 1889; Cory, 1909); however, the population declined from unknown causes in the early 1900's (Ridgway, 1915; Hankinson, 1916). In the 1950's kites were noted as rare in Illinois (Bennett, 1952; Smith and Parmalee, 1955). Although George (1971), Barbour et al. (1973) and Holt et al. (1974) stated that the population along the middle Mississippi Valley was increasing, the Illinois Department of Conservation (1977) considered the Illinois population vulnerable and the species endangered as a breeding population if present habitat losses continued. Graber and Graber (1976) noted that the state breeding population of kites was small and may represent the only endemic bird population in Illinois. Their use of endemic refers to the isolation from other populations of kites during the nesting season, and suggests no genetic exchange between them.

Because the life history and population size and status of Mississippi kites in Illinois were poorly known, a study was conducted to monitor nesting activities and reproductive success, band nestlings, determine food habits, and characterize nesting and feeding habitats.

Based on the literature (Hardin and Klimstra, 1976) and information from ornithologists, Union County appeared the center of the Mississippi kite population. The study area encompassed 2,230 ha and included portions of the Shawnee National Forest and the adjacent Union County Wildlife Refuge (UCWR), which was managed primarily for wintering Canada geese (Branta canadensis). Approximately 48 percent of the study area was in forest, 33 percent row crops, 9 percent water, 8 percent open areas, and 2 percent roads. Dominant trees were bottomland species and included willows (Salix spp.), cottonwoods (Populus deltoides), and sycamores (Platanus occidentalis). Clear Creek and an adjacent levee and road divided the study area.

Automobile and foot censuses were conducted throughout the study area. Four hundred sixty-four hours were spent censusing, observing, and banding kites between 1 April and 8 September 1977. As kites were observed, their location, habitat, and behavior were recorded; individual birds were followed in attempts to locate nests.

OBSERVATIONS

Mississippi kites were first observed on 9 May 1977 along the Clear Creek levee east of UCWR and appeared to be pair-bonded as copulation was recorded on that date. Subsequently, six other pairs were observed copulating on 12 May, 18 May, 24 May, 31 May, and 22 June. During precopulatory behavior, males soared and dived for insects which they presented to the perched females. This was followed by mounting the females; copulation lasted 10 to 30 seconds.

Nest building activities were first noted on 10 May. Both the male and female collected nest materials from trees by snipping twigs with their beaks or by pulling them with their talons. They made successiv trips to collect twigs from the same tree, usually willow or oak (Quercus spp.). Nests in Union County were located about 20 m above the ground in sycamore, sweetgum (Liquidambar styraciflua), and cottonwood trees. They were constructed of sticks, lined with green leaves and averaged 40.6 cm by 34.4 cm and 10.2 cm deep.

All nests were located near large openings at edges of woods, and were inconspicuous from the ground. Nests 1, 3, and 4 were in a dense, 372-ha woods bordered on the west by Clear Creek levee and on the east by forested bluffs. Dominant trees were sycamores, maples (Acer spp.), willows, and cottonwoods ranging from 20 to 25 m tall with understory species sparse. Two clearcut areas, encompassing 17 ha, were at the north end of this woods; three small lakes of 20 ha were at the south end.

Nests 2 and 5 were in an 83-ha woods which contained two fields; nest 2 was 260 m north of a 2-ha field, and nest 5 was 60 m north of a 4-ha field. Dominant trees 15 to 25 m tall in the dense, mature woods were sweetgum, oak, elm (Ulmus americana), boxelder (Acer negundo), cottonwood, hickory (Carya spp.), and maple. This woods was bordered on the west by the 81-ha Grassy Lake; and, a road and water-filled ditch separated it from a 107-ha woods to the east.

Table 1. Nesting data for Mississippi kites, Union County, Illinois, 1977.

Nest	Tree Species	Incubation Began	Hatching Date	Fledging Date
1	Sycamore	30 May	1 July	1-13 August
2	Sweet Gum	20 May	20 June	24 July
3	Cottonwood	--	25 June[1]	26 July
4	Cottonwood	--	--	--
5	Cottonwood	25 May[1]	25 June[1]	1-13 August

[1]Approximate date.

Initiation of incubation was defined as the first date a bird remained consistently on the nest. For two nests, incubation began in late May (Table 1); both male and female kites participated. During daylight hours, an adult incubated the eggs for approximately two hours before its mate resumed the duties. There were no vocalizations when kites changed places; the arriving bird landed on the rim of the nest as the incubating bird took flight. The bird returning brought a leafy branch from willow, cottonwood, or hickory. As this bird settled on the nest, it tucked the leaves of the branch around the egg. While incubating, the adult kite frequently stood, re-arranged nesting material, changed position, and shaded the egg. Several authors (Goss, 1891; Bendire, 1892; Ganier, 1902; Robinson, 1957; Cranson, 1972) reported that kite nests were lined with leaves and suspected they aided in nest sanitation.

The first hatch occurred in nest 2 after incubation of 32 days. On 20 June, the male was observed feeding the nestling by regurgitation. Generally, the adults brooded the nestling for 10 days; after which the young bird was left alone. The period of incubation noted was consistent with reports by Bent (1937), of 31-32 days, Sutton (1939) of 29-31 days, and Robinson (1957) of 31 days.

Of five nests observed, three (nests 2, 3 and 5) contained one egg, one (nest 1) contained 2 eggs, and one (nest 4), no egg. While only one of the eggs in nest 1 hatched, the adults continued to incubate for approximately 3 weeks. This egg was removed and opened on 22 July; there was no embryo development.

Nest 4 was probably the second nest; the pair was copulating in the vicinity of the nest on 22 June. The following day, the male repeatedly collected twigs from an oak tree and placed them on the nest, which, when located on 7 July, contained fresh vegetation and small amounts of down. The adults did not defend this nest, but remained in

the vicinity throughout the summer. They possibly built a third nest, although its success was doubtful.

In Kansas, Texas, and Oklahoma, Parker (1974) assumed a clutch size of two and reported that kites in 26 of nearly 400 nests incubated an addled egg after the first had hatched. Other authors have reported that the usual clutch size for Mississippi kites was two eggs (Goss, 1891; Sutton, 1939; Pough, 1951; Sprunt, 1954); however, reports of clutch size varied between one and four. Based on our observations, an assumed clutch size of two for southern Illinois kites does not seem valid.

Four nestling kites, approximately 2 weeks old, were banded by first lowering them from the nest to the ground in a bag. They were weighed, measured, marked with colored plastic and U. S. Fish and Wildlife Service leg bands, and returned to the nest (Table 2). Tree climbing, handling, and banding of nestlings did not cause abandonment by adults or loss of young. All banded nestlings fledged successfully and bands did not appear to interfere with flight or prey capture.

Fledging was at about 34 days; all had fledged by 13 August. Initially, 1 or 2 days were spent perched on branches within 3 m of the nest; they gradually moved farther from it. Fledglings remained in the general vicinity of the nest until they left the breeding area. These data support Robinson (1957) and Parker (1974) who noted that Mississippi kites of the Great Plains fledged at 28 to 35 days.

Newly hatched kites were fed by regurgitation on the average of every 16.4 minutes during early morning (0800-1000) and late afternoon (1600-1800). Both adults provided cicadas, grasshoppers, small toads, beetles, and dragonflies to 1-week-old nestlings by tearing food into small pieces. Entire insects were fed to young when about 2 weeks old. Fitch (1963) reported that adults in southwestern Kansas carried food in their throats to young kites every 10.7 minutes.

Table 2. Weight, length, and band information for nestling Mississippi kites, Union County, Illinois, 1977.

Nest	Weight	Length[1]	Approximate Age	Date Banded
1	160 g	15.9 cm	12 days	12 July
2	185 g	20.3 cm	17 days	7 July
3	130 g	16.5 cm	10 days	5 July
5	195 g	19.1 cm	20 days	15 July

[1]Length from tip of beak to base of tail.

Fledgling kites hunted for food and continued to be fed by adults, usually the male, until they left the breeding area. During one afternoon, an adult fed six grasshoppers to a fledgling within 12 minutes.

Prey capture and feeding by kites was as described by Wilson (1811), Brewer (1853), Goss (1891), May (1935), Bent (1937), Pough (1951), Skinner (1962), and Fitch (1963). They fed while in flight, capturing insects in the air; occasionally an item was taken from the ground. In most instances, food items were transferred from talons to the beak. Food in southern Illinois consisted of small unidentified insects, beetles, grasshoppers, cicadas, dragonflies, and butterflies. Kites in Union County fed in a variety of habitats which included fallow fields, mixed bottomland woods, and levee roads with adjacent areas of annual vegetation.

Mississippi kites were most active at mid-day (1000-1400) and late afternoon (1600-1800). In early morning they were often perched in trees near the nest, while in late morning they fed, soared and returned to perches in mid-afternoon. During late afternoon there was some evidence of group feeding.

Several hours per day were spent perched, usually on a dead branch or snag that provided visibility in most directions. At this time they preened, disgorged pellets, and sunned with tail feathers spread and wings partially opened. In 6 years of observations in Illinois bottomlands, Fleig (1972) reported kites perched only once.

The breeding population of Mississippi kites at UCWR and adjacent Shawnee National Forest was estimated at 13 pairs of adults based on sightings of paired birds. Although only five nests were located, 10 different fledglings were observed. During 15 June to 1 July feeding concentrations of up to 36 kites were observed over a fallow field at UCWR. At this time, feeding occurred mainly in mid-day to late afternoon, and involved birds in both adult and yearling plumage. Because this was when birds were incubating eggs, participants may have been mates of incubating birds. However, it is more likely that a number of non-nesting transients were involved because yearling birds were not seen after the end of June. These transient birds may have represented "floating" or non-breeding yearling kites; but, there are no reports of a non-breeding kite population of any age. Parker (1974) noted that approximately 10 percent of the Kansas, Texas, and Oklahoma breeding population consisted of yearling birds and that yearling birds successfully paired with adults. In southern Illinois, no breeding yearlings were noted; however, those in yearling plumage were observed with each of four nesting pairs. Cranson (1972) and Parker (1974) also observed non-breeding yearling kites in the vicinity of nesting adults in southwestern United States. Possibly, yearling kites returned to the breeding ground with the adults and dispersed in late June. This possible "floating" population of non-breeders may account for large feeding concentrations observed from 15 June to 1 July.

Extensive tracts of mature, mixed bottomland timber interspersed with agricultural lands, open areas of annual vegetation and water

provided nesting and foraging sites for Mississippi kites in Union County. The variety of mature trees and open areas that supported numerous large insects, seemed extremely important, as the birds were not found where cottonwood trees and agricultural crops were the dominant vegetation. Because the largest aggregation in Illinois of breeding and foraging kites was found at this locality, it is important to preserve the combination of habitats and evaluate the characteristics which make them suitable for this species.

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POLLINATION BY ANTS IN THE ALPINE TUNDRA OF COLORADO

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ABSTRACT: Insect visitors to flowers of Eritrichium aretioides (Champ.) D. C. (Boraginaceae) included 73 Leptothorax canadensis Provancher (Hymenoptera: Formicidae), 13 Formica neorufibarbis gelida (Wheeler) (Hymenoptera:Formicidae), and 62 individuals of 10 other species. Umbells of Oreoxis alpina (Gray) C. and R. (Umbelliferae) were visited by 240 F. n. gelida, 66 L. canadensis, and 121 times by 8 other species. Specimens of Thlaspi alpestre L. (Cruciferaceae) were visited by Phyllotreta albionica Lec. (Coleoptera: Chrysomelidae) 138 times, F. n. gelida 40 times, and other insects 20 times. These three species which are predominantly cross-pollinated by ants blossom in early June on the Colorado alpine tundra. Pollen grains from all three species of plant were found on F. n. gelida, and E. aretioides pollen was found on L. canadensis.

These plants show most of the characteristics proposed by Hickman for ant-pollinated plants: accessable nectaries; short stems; grow in dense stands; are members of an impoverished flora; few synchronously blooming flowers per plant; sessile flowers; pollen grains few and of small size: few seeds per flower; small, plain flowers; and small quantity of nectar.

The environmental conditions of the alpine tundra appear to provide the two species of high altitude ants a niche occupied by flying pollinators in most other ecosystems.

INTRODUCTION

Hickman (1974) found that Polygonum cascadense Baker (Polygonaceae) is pollinated by Formica argentea Wheeler (Hymenoptera:Formicidae) on the hot, dry slopes of the Western Cascades of Oregon. He summarized the literature on pollination by ants and listed a syndrome of ten traits in P. cascadense that suited it for pollination by ants.

He compared other ant-pollinated plants to his proposed syndrome and found 90-100% matches.

In studying the pollination of some alpine plants at 3510 M. altitude on Niwot Ridge in Boulder County, Colorado (Petersen, 1968), I observed that ants were major insect pollinators of three species of plant: Thlaspi alpestre Linnaeus (Cruciferae), Eritrichium aretioides (Champ.) De Candole (Boraginaceae), and Oreoxis alpina (Gray) Colter and Rose (Umbelliferaceae). T. alpestre pollination is described in Petersen (1977), the pollination of the other two species is described here and all three plant species are compared with other ant pollinated flowers according to the 10 traits discussed by Hickman (1974).

Eritrichium aretioides

In the summer of 1965, which had typical weather conditions, E. aretioides anthesis began in mid-June and peaked by June 25. The plants are perennial cushions with small, entire, densely clustered leaves on short branches with bright blue flowers in racemes (Harrington, 1954). The corolla has a short crested tube with included stamens (Harrington, 1954). It has a wide distribution from eastern Europe across Siberia to the Yukon (Polunin, 1959); and in the alpine tundra of western United States (Rydberg, 1906). It is a member of cushion plant communities which grow on solifluction lobes, meadows, and other extremely windy sites (Willard, 1963; Marr, 1961).

Oreoxis alpina

O. alpina plants are 2-10 cm. tall and puberulent with oblong, pinnate leaves, yellow flowers, pubescent fruit, and oil tubes in intervals (Harrington, 1954). It is found only in the mountains of Utah, Wyoming, Colorado, Arizona, and New Mexico. Weber (in Rodeck, 1964) reports that it is a desert-steppe species with a race in the alpine. It is found in well-drained sites in the low alpine in cushion plant communities. It is a fellfield plant capable of withstanding harsh winds and prolonged snow cover (Marr, 1961; Willard, 1963). Anthesis begins by mid-June. Flowers appeared by June 1 in 1967, a year of light snowfall. Blossoms are common by the third week of June. (Petersen, 1968).

METHODS

E. aretioides and O. alpina flowers were examined for adaptations to insects such as color, size and number of blossoms on an anthium. In 1967, pieces of very fine cloth were tied over the anthia of E. aretioides and O. alpina plants with 95 and 77 flowers respectively, before anthesis, to exclude pollinators, and so to determine if the plants were self-sterile. To determine if the plants were agamospermous, stigmas were removed from ten flowers of each before anthesis. Later these plants were examined for fruit.

Each observation of an insect to a flower was recorded. Specimens of each species of insect were capture, microscopically examined, and identified. Common visitors were observed to determine their activities at the flower. About 100 hours of observations of each

plant species were made at various times during both clear and overcast days, during the flowering seasons of 4 summers. Most observations were made between 0800 h. and 1200 h. Mountain Standard Time when insects were most active.

Specimens of Formica neorufibarbis gelida were placed in a chamber of a refrigerator and examined after they were cooled to determine if their mobility was impared by cold temperature.

The plants were compared to Hickman's (1974) list of 10 traits suggested for ant-pollinated flowers: (1) Plants must grow in those hot and dry habitats where the frequency and activity of ants is high. (2) Their nectaries must be readily accessable to a small, short-tongued insect. (3) Plants must be short or prostrate. (4) Populations must be dense or stands must contain few species. Plants so dense as to have interdigitating branches have lessened strictures on height. (5) Synchronously blooming flowers must be few per plant, since many attractive flowers will maximize intra-plant rather than interplant pollen transport. (6) If plants are erect, flowers must be sessile; if plants are matted, flowers must be on mat surfaces. (7) Pollen volume per flower must be small to avoid stimulation of self-grooming. This can be achieved by reducing the number of pollen grains, their size, or both. (8) Seeds must be few per flower. (9) Flowers must be small and of minimal visual attraction. (10) Nectar quantity must be too small to support flying pollinators whose energy demands while foraging exceed the available award.

RESULTS AND DISCUSSION

"The Ant Pollination Syndrome"

Obviously, the first characteristic on Hickman's list, a hot dry habitat, is not found in the Niwot Ridge study area where the daily mean high temperature in June is 6°C. However, there are two ant species that are very common there: Formica neorufibarbis gelida Wheeler and Leptothorax canadensis Provancher (Hymenoptera:Formicidae) (Greeg, 1963). Many rocks greater than 20 cm. in diameter harbor a colony of L. canadensis. During sudden storms both species of ants find shelter close by. The ants are dark, as is characteristic of high altitude insects (Mani, 1962, 1968). Their dark color can absorb radiant energy to raise their temperature. They live in a microhabitat that is out of the wind with its cooling, drying effect. F. n. gelida was placed in a chamber and cooled to 1°C in a refrigerator and would still crawl. L. canadensis were observed crawling slowly on the ground, out of the sun at 2°C at the study site.

T. alpestre possess the remaining 9 characteristics listed by Hickman: (2) The nectaries are readily accessable to a small, short-tongued insect as is illustrated in Petersen (1968). (3) It has short stems (Harrington, 1954) and is often dwarfed in the alpine parts of its range (Rachow, 1970). (4) Populations are usually dense and the flora of alpine regions is impoverished relative to more temperate sites (Billings & Mooney, 1968). Their interdigitating branches often form pseudanthia (Petersen, 1977). (5) There are generally only one or two blossoms on an anthium that are fully open

at a time. (6) The flowers are sessile (Harrington, 1954) with (7) pollen grains that measure 37 x 17 microns and are few in number (Petersen, 1968; Pope, 1925). (8) Seeds are few per flower. (9) The flowers are 0.5 cm. across when opened fully and are white with (10) small nectaries (Knuth, 1898-1905).

Hickman's ant-flower syndrome can be applied to E. aretioides blossoms too: (2) They measure 4 mm. or less across with a corolla tube diameter of about 0.5 mm. which excludes all but the smallest insects and insect tongues (Petersen, 1968). A droplet of nectar nearly fills each tiny corolla tube. (3) The stems are seldom over 6 cm. long (Harrington, 1954). (4) They are common plants in floristically impoverished sites (Willard, 1963). (5) There are many blossoms on a cushion (Petersen, 1968) and (6) they are sessile (Harrington, 1954). (7) The pollen grains measure 3 x 8 microns and are shaped like bow ties (Petersen, 1968). (8) Seeds are 4 per flower (Knuth, 1898-1905). (9) The flowers are very showy being bright blue with yellow nectar guides, but are small, between 1.5 and 4 mm. in diameter (Petersen, 1968; Harrington, 1954). (10) They provide a lot of nectar for their size, but are very small. Except for traits, 1, 9 and 10, E. aretioides flowers fit the proposed ant-flower syndrome. Their concordance would be about 8 out of 10 items.

O. alpina plants have (2) nectaries accessable to small short-tongued insects, (3) short stems (Harrington, 1954), (4) dense stands in impoverished plant communities (Willard, 1963), (5) few synchronously blooming flowers, (Petersen, 1968), (6) sessile flowers (Harrington, 1954), (7) pollen grains 12 x 22 microns and few in number (Petersen, 1968), (8) few seeds per flower, (9) flower less than 4 mm. in diameter (Harrington, 1954) and (10) very small quantities of nectar. These traits give O. alpina 90% fit with the Ant Pollination syndrome.

Thlaspi alpestre

T. alpestre was found to be pollinated by Phyllotreta albionica Lec. (Coleoptera:Chrysomelidae) and Formica neorufibarbis gelida Wheeler (Hymenoptera:Formicidae) (Petersen, 1968, 1977). F. n. gelida were captured on T. alpestre and examined for pollen, which was found on all of them.

Eritrichium aretioides

Forty-two percent of the flowers covered to exclude pollinators set seed (40 of 95) indicating that self-fertilization is rather frequent while 58% of the control flowers produced seeds. None of the flowers with their stigmas removed set seed so E. aretioides does not appear to be agamospermous.

Of 148 insects observed to visit E. aretioides, 73 were L. canadensis, 13 F. n. gelida, 14 Quadrularia laetifica (R. - D.) (Diptera:Muscidae), 24 by 3 other species of flies, and 24 were visits by 6 other species. Recorded visits by L. canadensis nearly equalled the number of visits by all 11 other species combined. None of the flying insects showed any species constancy at all and I do not

believe they play a role in the pollination of E. aretioides. Q. laetifica, for instance, was observed to visit T. alpestre 8 times, Primula angustifolia 4 times, Draba streptocarpa 10 times, Phlox pulvinata 6 times and Silene acaulis once. They frequently flew from flower, to rock, to leaf, to me, to my lunch, and to a flower of another species without any abiding interest in any of them.

The role of flying pollinators was limited by the few hours of good flying weather on the tundra in the spring. Flying insects must cope with high wind velocity, cold temperature, and food shortage; so while their energy requirement is heightened, their energy supply is reduced (Hickman, 1974; Mani, 1962, 1968; Marr, 1961; Billings and Mooney, 1968). Data gathered by the Institute for Arctic and Alpine Research show the average wind velocity is 5.35 M per second and the average temperature is 6^{o}C in June on Niwot Ridge near the study site. Flying insects are observed there only on the warm, calm parts of the warm days.

On visiting an E. aretioides flower, L. canadensis crawls inside and stays for a long period of time with only its gaster showing. After ten minutes, or even longer, in a flower, the ant emerges and goes to another flower. The pollen is carried from one flower to the next on the bristles covering its body. (See photograph in Petersen, 1968). L. canadensis are small insects, measuring only 1 mm. in length. The larger F. N. gelida cannot insert its head into the corolla of E. aretioides. I have observed it dipping an antenna into the corolla then draw it between its mandibles.

Estes and Brown (1973) report that insects aid in the self-pollination of Phyla incisa by rummaging around within the blossom. The percent of selfing in E. aretioides may be increased by this means, too, although perhaps a temporal separation of stigma and anther maturation reduces the frequency of this event.

Oreoxis alpina

O. alpina pollen grains are shaped like rice grains with a longitudinal suture around them. Flowers with their stigmas removed did not set seed indicating that O. alpina is not agamospermous.

Self-fertilization is delayed in O. alpina by the stigmas maturing and protruding from the flower while the anthers are still held within the tightly closed petals. As the petals open, the anthers ripen and appear too, but self-pollination does not occur readily. Of 77 covered flowers, only 4 (6%) set seed. Seed set of the control flowers was also low: 17 seeds from 151 flowers (11%).

Insects are common visitors to O. alpina: 240 F. n. gelida were observed, 66 L. canadensis, 61 Philygra debilia L. W. (Diptera), and 22 by 5 other insect species. Nearly 3/4 of the 427 visits observed were by ants and over 1/2 of the total were by F. n. gelida. Sixteen of 20 ants captured on or near O. alpina were carrying pollen on the bristles covering their bodies.

Visits by Ants to other Alpine Flowers

F. n. gelida were commonly seen on Lloydia serotina and Paronychia sessiflora var. pulvinata, and I believe that a careful study of these species would disclose that ants are their major cross pollinators. Visits by F. n. gelida to Draba streptocarpa Gray (Cruciferae) were recorded 35 times, visits to Phlox pulvinata Cronquist (Poleomiaceae) 14 times, and to Silene acaulis L. (Caryophyllaceae) 38 times (Petersen, 1968). All of these alpine flowers appear to have a high concordance with the syndrome proposed by Hickman for ant-pollinated flowers. Many more thorough observations of F. n. gelida should be made to determine its complete role in tundra flower pollination.

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GASTROINTESTINAL HELMINTHS OF THE MUSKRAT, *ONDATRA ZIBETHICUS*, IN SOUTHERN ILLINOIS

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ABSTRACT.--Two hundred and nine muskrats, *Ondatra zibethicus*, collected from three ecologically similar counties in Southern Illinois, were examined for gastrointestinal helminths and 139 infected muskrats harbored one or more of the following species: *Echinostoma revolutum*, *Quinqueserialis quinqueserialis*, *Ascaris* sp., *Capillaria* sp., *Nematospiroides longispiculata*, and *Rodentolepis evaginata*.

The distribution, host specificity and life cycles of wildlife parasites have been emphasized (Allen, 1934; La Rue, 1933; Swales, 1933; Van Cleave, 1937) as important factors in determining guidelines for wildlife management programs. Wild animals with high population densities and wide distributions may distribute their parasites to numerous habitats and other species of animals. The importance of such hosts in the epizootiology of diseases of wildlife species as well as certain zoonoses of human and domestic animals has resulted in an increasing interest in their parasites by parasitologists, wildlife personnel, veterinarians, and physicians.

Although *Ondatra zibethicus* (Linnaeus 1776) is primarily herbivorous, occasional insectivorous and carnivorous tendencies increase its exposure to a wide variety of parasites. When considering the importance and value of the muskrat as a wildlife entity, data concerning parasitism is pertinent to understanding its ecology.

Little information is available on the parasitic fauna of muskrats in Illinois. Leigh (1940) reported *Echinostoma revolutum* (Froelich 1802) and *Notocotylus filamentis* (Barker 1915) from muskrats in his preliminary investigations on parasites of upland birds and fur-bearing animals in Illinois. Gilford (1954) examined a total of 250 muskrats collected between 1951 and 1952 from northern and middle zone counties of Illinois and reported an incidence of infection of 56.9% and 54.5% respectively. Arata (1959) reported one specimen of *Monoecocestus* sp. in the large intestine of a single muskrat and *Quinqueserialis quinqueserialis* (Barker and Lauchlin 1911)

in the caecum and/or large intestine of 13 of 36 muskrats examined from strip-mine ponds in Perry County, Illinois. Since there is a paucity of information on the parasitic fauna of muskrats in southern Illinois, the present investigation was undertaken to determine the incidence of gastrointestinal helminths in hosts from this area.

Reviews of the literature on the parasites of muskrats in North America have been included in reports of Barker (1915), Harkema (1936), Takos (1940), Meyer and Reilly (1950), Knight (1951), Beckett and Gallicchio (1967) and Sey (1967). As an aid to investigators interested in the helminths of muskrats, Table 1 identifies the literature in North America from 1967 to 1977.

MATERIALS AND METHODS

Two hundred and nineteen muskrats, collected from three ecologically similar counties (Jackson, Union and Williamson) in southern Illinois between March, 1971 and March, 1972 by personnel of the Cooperative Wildlife Research Laboratory of Southern Illinois University at Carbondale, were examined for gastrointestinal helminths. The majority of hosts were trapped; a few were road killed. Organs of the gastrointestinal tract, stomach through large intestine, of each muskrat were examined separately for helminths.

Trematodes and cestodes were killed and fixed in hot A.F.A., stained with either Ehrlich's hematoxylin or Mayer's acid carmalum, destained, dehydrated, and gradually cleared by successive treatment for several hours in 25, 50, 75 and then 100% beechwood creosote. Fast green in 95% ethanol was used to counterstain the cephalic spines of echinostomes. Nematodes were cleared in glycerine and studied in temporary mounts. The anterior ends of some specimens were removed and mounted in glycerine jelly for *en face* studies.

RESULTS AND DISCUSSION

Of the 209 muskrats examined, 139 (66.5%) were infected with one or more helminths (Table 2). One hundred and nineteen (85.6%) hosts were positive for one parasitic species and 20 (14.4%) for two. Parasites occurring as a single infection and the number and percentage of hosts infected with these species were *Echinostoma revolutum* (Froelich 1802), 98 (70.5%); *Quinqueserialis quinqueserialis* (Barker and Lauchlin 1911), 14 (10.1%); *Nematospiroides longispiculata* Dikmans 1940, 3 (2.2%); *Ascaris* sp., 1 (0.7%); *Capillaria* sp., 1 (0.7%); and *Rodentolepis evaginata* (Barker and Andrews 1915), 2 (1.4%). *Quinqueserialis quinqueserialis* and *E. revolutum* occurred as a mixed infection in 19 (13.7%) of the hosts examined and *Q. quinqueserialis* and *N. longispiculata* in 1 (0.7%). Both sexes were parasitized to about the same extent, helminths being

TABLE 1. HELMINTHS FROM NORTH AMERICAN MUSKRATS REPORTED BETWEEN 1966 AND 1977.

Species	Locality	Reference
Trematoda:		
Echinochasmus schwartzi	Maryland	Abram, 1969
Echinostoma revolutum	Pennsylvania	Anderson and Beaudoin, 1966
	Utah	Grundmann and Tsai, 1967
	British Columbia	Doerksen, 1969
	Maryland	Abram, 1969
	Ohio	Rice and Heck, 1975
Fibricola cratera	Utah	Grundmann and Tsai, 1967
Notocotylus urbanensis	Utah	Grundmann and Tsai, 1967
Nudacotyle novicia	Maryland	Abram, 1969
Paragonimus kellicotti	Kentucky	Harley, 1972
Paramonostomum pseudaliviatum	Utah	Grundmann and Tsai, 1967
Plagorchis proximus	Utah	Grundmann and Tsai, 1967
Psilotrema sp.	Utah	Grundmann and Tsai, 1967
Ptyalincola ondatrae	Michigan	Wooton and Murrell, 1967
Quinqueserialis quinqueserialis	Pennsylvania	Anderson and Beaudoin, 1966
	Utah	Grundmann and Tsai, 1967
	Maryland	Abram, 1969
	Ohio	Rice and Heck, 1975
Wardius zibethicus	Pennsylvania	Anderson and Beaudoin, 1966
	Utah	Grundmann and Tsai, 1967
	Maryland	Abram, 1969
	Ohio	Rice and Heck, 1975
Cestoda:		
Andrya sp.	Utah	Grundmann and Tsai, 1967
Hymenolepis ondatrae	Utah	Grundmann and Tsai, 1967
Taenia taeniaeformis	Pennsylvania	Anderson and Beaudoin, 1966
	Maryland	Abram, 1972
Nematoda:		
Ascaris sp.	Utah	Grundmann and Tsai, 1967
Capillaria michiganensis	Ontario	Webster, 1966
	Utah	Grundmann and Tsai, 1967
Dracunculus insignis	Ontario	Gibson and McKiel, 1972
Dracunculus sp.	Ontario	Crichton and Beverley-Burton, 1974
Eustrongylides sp.	Ontario	Gibson and McKiel, 1972
Trichuris opaca	Utah	Grundmann and Tsai, 1967
	Maryland	Abram, 1969
	Ohio	Rice and Heck, 1975

recovered from 69 (68.3%) and 70 (64.8%) of 101 male and 108 female hosts, respectively.

With the exception of Ascaris sp., all helminths recovered in this study are widely distributed in muskrats in the contiguous United States. It is not surprising that trematodes were much more common than either nematodes or cestodes as flukes are usually present in rodents such as the muskrat whose habitat is either in or near bodies of water. The high prevalence of E. revolutum may reflect the presence of numerous hosts which in addition to the muskrat may serve as part of the reservoir for the parasite (Beaver, 1937).

The least common parasites recovered were Ascaris sp. and Capillaria sp. To our knowledge, only three reports (Barker, 1916; Tiner and Chin, 1948; Grundmann and Tsai, 1967) have included Ascaris sp. The identity of the capillarids could not be ascertained as all specimens were immature. These are probably either Capillaria ransomia Barker and Noyes 1915, or C. michiganensis (Read 1949) which have been reported in muskrats from other areas. This is the first report of a capillarid from muskrats in Illinois. The finding of Rodentolepis evaginata in only 1.4% of the animals examined corresponds to the low incidence of 0.4% as reported by Gilford (1954) from muskrats in northern Illinois.

TABLE 2. INTESTINAL HELMINTHS RECOVERED FROM 209 MUSKRATS IN SOUTHERN ILLINOIS.

Species of helminth	Location of host	No. animals infected	Percent infected
Trematoda:			
Echinostoma revolutum	small intestine	117	84.2
Quinqueserialis quinqueserialis	caecum	34	24.5
Cestoda:			
Rodentolepis evaginata	small intestine	2	1.4
Nematoda:			
Ascaris sp.	small intestine	1	0.7
Capillaria sp.	small intestine	1	0.7
Nematospiroides longispiculata	small intestine	4	2.9

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THE CUTICULAR AMINO ACIDS IN THE DOG HEARTWORM (DIROFILARIA IMMITIS)

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ABSTRACT - The amino acid composition of acid-hydrolysates from the cuticular protein of adult female Dirofilaria immitis was determined by one and two-dimensional thin layer chromatography. The cuticular protein was found to contain the following amino acids: alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, hydroxyproline, isoleucine, leucine, lysine, phenylalanine, proline, serine, threonine, and valine.

INTRODUCTION

The nematode cuticle generally consists of the cortex, middle, and basal layers which contain protein, lipid, and carbohydrate. Investigators agree that the nematode cuticle is primarily protein. The protein in the inner two layers has sometimes been identified as collagen because of its physical and chemical properties.

The identification of the cortex protein is not as certain. Work by Chitwood (1936), Flury (1912), and Savel (1955) identify this protein as keratin. Other studies by Faure-Fremiet and Garrault (1944), and Fairbairn (1957) indicate collagen as the cortex protein. Bird and Bird (1969), aware of this uncertainty wrote that perhaps "nematode cuticles are made up of secreted collagens unique to and characteristic of the Nematode....".

The amino acids in some adult nematode cuticles and in larval sheaths have been investigated. Bird (1954) identified nine amino acids in the hydrolysate of mixed larval sheaths of Haemonchus contortus, Trichostrongylus spp., and Nippostrongylus muris.

According to Savel (1955) the whole Ascaris lumbricoides cuticle contains thirteen amino acids.

Using paper chromatography, Bird (1956) isolated sixteen amino acids in whole cuticle hydrolysates of Ascaris, Toxocara, and Strongylus. Bird (1957) also surveyed the amino acids present in each Ascaris cuticle layer. In this particular investigation, Rees and Baston (unpublished data) identified seventeen amino acids.

Watson and Silvester (1959) also analyzed the entire Ascaris cuticle. General agreement exists between Watson and Silvester (1959) and Bird (1957) in the quantities of amino acids present. One exception is the amino acid valine. Watson and Silvester (1959) found much less of this amino acid than did Bird (1957).

Bird (1958) identified sixteen amino acids in the cuticle of Meloidogyne, a plant parasitic nematode.

Cuticle analysis of Anisakis physteris by Viglierchio and Gortz (1972) revealed twenty amino acids. Results indicated that 69% of cuticular amino acid nitrogen was contained in glutamic acid, glycine, serine, proline, and arginine.

An increasing awareness of the dog heartworm, D. immitis, in the Midwest and the problems it causes, have resulted in amino acid studies using this nematode. Jaskoski and Fitko (1974) identified sixteen amino acids in the whole worm hydrolysates of male and female D. immitis. The present investigation was undertaken to reveal the amino acids present in the cuticle of adult female D. immitis.

MATERIALS AND METHODS

Various methods of removal of the dog heartworm cuticle involving trypsinization, as is possible for the Ascaris cuticle, failed. Mechanical and manual methods were used in the present study.

Eighty-seven mg of cuticle were removed from eight thawed female D. immitis. To remove the cuticle, the dehydrated worms were cut into one inch pieces and ground in a tissue grinder containing 6 ml triple distilled water. Once the cuticle was noticeably loosened when viewed under the dissecting microscope, a scalpel and probe were used to remove any non-cuticular material from the sample. All work was done with the aid of the dissecting microscope.

The pure sample was then washed three times in 10 ml triple distilled water in a centrifuge at 925 rpm for 10 min. Following the washings, the sample was dried in a desiccator.

Lipid Extraction

Cuticular lipid was separated from cuticular protein. The pure dried cuticle sample was placed in a 250 ml Erlenmeyer flask containing 25 ml diethyl ether and the flask was covered with aluminum foil. Six times during the next 48 hrs, the flask was removed from a Burrell wrist action shaker and the contents centrifuged at 3000 rpm for 4 min. The cuticle was resuspended in an additional 25 ml diethyl ether and then returned to the shaker after each centrifugation.

Acid Hydrolysis

After lipid extraction, the cuticle sample was placed in a 50 ml beaker containing 3 ml fresh diethyl ether which was evaporated in dryness at room temperature.

After adding 4 ml 6N HCl to the dried sample, the beaker contents were poured into a 5 ml ampoule. The sealed ampoule was suspended by a wire attached to a ring stand for 24 hrs in 300 ml mineral oil calibrated at 110°C in a heating mantle. Following hydrolysis, the ampoule contents were filtered and then evaporated 6 times in 10 ml triple distilled water. Evaporations were performed on a watch glass placed four inches above a hot plate. The resulting residue was dissolved in 10% isopropanol and the solution restored to neutrality with the addition of .2M Gomori phosphate buffer.

Thin Layer Chromatography

One and two dimensional chromatograms of the acid hydrolysate were run on Eastman Chromagram Sheets, No. 13181, with fluorescent indicator. The adsorbent was a 100 micron thick silica gel layer with a polyvinyl alcohol binder.

Plain capillary tubes measuring 75 mm long with an inner diameter of 1.1-1.2 mm were filled with the acid hydrolysate and touched sixty times to the chromatogram sheet. Amino acid standards were spotted three times each, and all spotting was done under a flow of cool air.

The solvent used for the one dimensional chromatograms and as the first solvent in the two dimensional chromatograms was n-butanol:glacial acetic acid:water (8:2:2). The two dimensional chromatograms were dried at room temperature with cool air for five min before being rotated 90 degrees and placed in the second solvent, n-propanol:water (7:3). The solvent advanced 15 cm on the silica gel sheets and the time in each solvent was 8 to 9 hours.

After removal from the second solvent, the sheets were dried under a cool air stream for 5 min and then sprayed with ninhydrin prepared according to Stahl (1965). A hot air stream was directed at the sheet until the colored spots appeared. R_f values were determined for the amino acids appearing in the acid hydrolysate and compared with the R_f values of the amino acid standards in order to identify the amino acids present in the filtrate. The calculated values were also compared with the results of other personnel who performed similar studies in this laboratory.

The one and two dimensional amino acid standard chromatograms were run and processed in the same manner as described for the filtrate.

RESULTS

Fifteen amino acids (alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, hydroxyproline, isoleucine, leucine, lysine, phenylalanine, proline, serine, threonine, valine) were identified on chromatograms of acid hydrolysates of adult female Dirofilaria immitis cuticle (Fig. 1). The R_f values plus the position of the colored spots on the chromatograms were compared with an unpublished study done in this laboratory on Ascaris cuticle and also with Jaskoski and Butler's (1971) study of the tick egg shell amino acids. A two dimensional chromatogram spotted with control amino acids was then run alongside a two dimensional chromatogram of the acid hydrolysate.

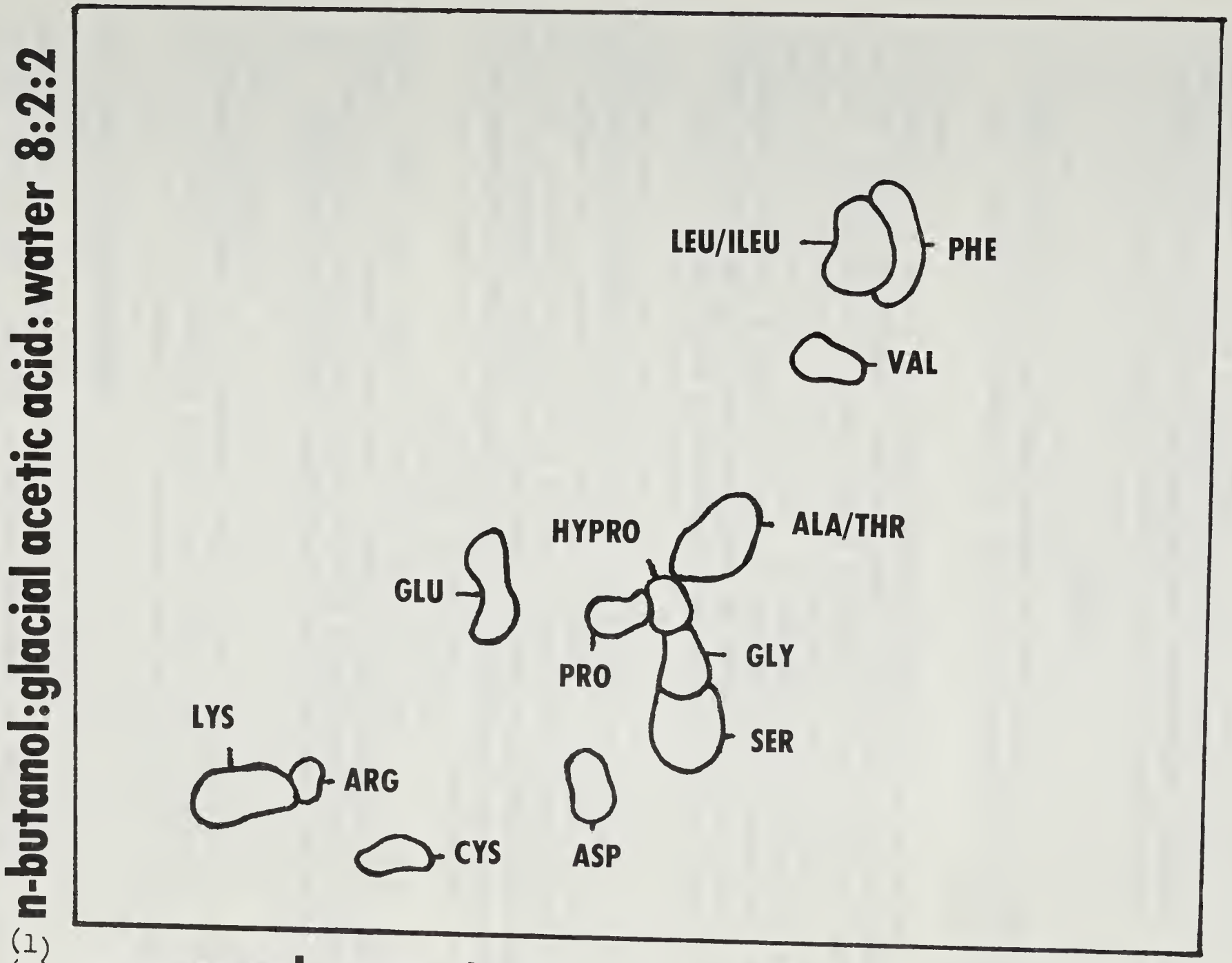

Figure 1. Two-dimensional chromatogram of amino acids in acid hydrolysate of D. immitis

DISCUSSION

Because Fairbairn (1957) has reported that the nematode cuticle is basically protein, an amino acid analysis of the adult female dog heartworm cuticle was done. A comparison of the results of several investigations of the amino acid content of the cuticles of Ascaris, Anisakis, a plant parasite (Meloidogyne), and a filariid worm, D. immitis is shown (Table 1).

A study of the results in Table 1 shows a general similarity in the cuticular amino acids of Ascaris lumbricoides var suum, Anisakis physteris, Meloidogyne, and Dirofilaria immitis. This similarity is noteworthy considering the wide habitat range of these nematodes. Ascaris is an intestinal parasite in the pig; Anisakis is found in the gastric lumen or attached to the mucosa of the sperm whale; Meloidogyne is a plant parasite; and D. immitis is a blood parasite in the dog.

No major differences are evident in the amino acid comparison of several nematode cuticles. Cysteic acid, histidine, tyrosine, tryptophan, and methionine have been found in various investigations of the Ascaris cuticle, but not in the heartworm cuticle. Histidine, methionine, tryptophan, and tyrosine were found in the Anisakis cuticle, but not in the heartworm cuticle. The Meloidogyne cuticle contains cysteic acid, histidine, and tyrosine which are not found in the heartworm cuticle. On the other hand, D. immitis cuticle contains phenylalanine and serine which have not been identified in the Meloidogyne cuticle.

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Table 1. Amino acids identified in nematode cuticles

Amino Acid	Bird 1956 (Ascaris)	Bird 1957 (Ascaris) (layers)	Watson & Silvester 1959 (Ascaris)	Firlit* (Ascaris)	Viglierchio & Gortz 1972 (Anisakis)	Bird 1958 (Meloi-dogyne)	Present Study D. immitis
Alanine	+	+	+	+	+	+	+
Arginine	+	+	+	+	+	+	+
Aspartic acid	+	+		+	+	+	+
Cystine	+	+		+	+	+	+
Cysteic acid	+					+	
Glutamic acid	+	+		+	+	+	+
Glycine	+	+	+	+	+	+	+
Histidine	+	+	+	+	+	+	
Hydroxy-proline	+		+	+	+	+	+
Isoleucine		+	+	+	+	+	+
Leucine	+	+	+	+	+	+	+
Lysine	+	+	+	+	+	+	+
Methionine		+	+	+	+		
Ornithine					+		
Phenylalanine		+	+	+	+		+
Proline	+	+	+	+	+	+	+
Serine		+	+	+	+		+
Threonine	+	+	+	+	+	+	+
Tryptophan	+				+		
Tyrosine	+	+	+	+	+	+	
Valine	+	+	+	+	+	+	+

*unpublished data

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ADDITIONS TO THE LICHEN FLORA OF ILLINOIS

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ABSTRACT

Fifty-two species of lichens are reported from Illinois for the first time.

Early floristic reports on lichens of Illinois include: Willey (1877, 1878), Wolf and Hall (1878), Calkins (1896), and Fink (1906). Brendel (1887) listed 35 species from around Peoria. By 1935 when Fink's THE LICHEN FLORA OF THE UNITED STATES was published, 240 species were known from Illinois. Subsequently, our knowledge of Illinois lichens has increased thanks to ecological studies including Winter-ringer and Vestal (1956), Stotler (1976), to taxonomic studies of genera in North America such as Sierk (1964), and to floristic studies by Hartline (1938), Skorepa and Snider (1967), Skorepa (1970, 1973), and Wiedman and White-side (1975). Such studies combined with the present report of 52 state records have increased the number of lichens known from Illinois to about 360. The specimens cited below are in the SIU Herbarium or in my personal lichen collection.

LIST OF SPECIES

Acarospora schleicheri (Ach.) Mass. SALINE CO.: Murray Bluff, Ozment s. n.

Bacidia naegelii (Hepp) Zahlbr. JACKSON CO.: Grand Canyon, 4003. On a tree in mesic woods.

Buellia curtisii (Tuck.) Imsh. POPE CO.: Bell Smith Springs, 6801. On trees in old fields and open woods.

Buellia pullata Tuck. SALINE CO.: Murray Bluff, Ozment s. n. On sandstone in upland woods.

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Buellia stigmaea Tuck. POPE CO.: Lusk Creek Canyon, 3184. On sandstone in creeks and on bluffs.

Buellia vernicoma (Tuck.) Tuck. POPE CO.: Lusk Creek Canyon, 517. On sandstone in full to filtered shade.

Caloplaca citrina (Hoffm.) Th. Fr. UNION CO.: Pine Hills, 802. Common on dry limestone and concrete.

Caloplaca discolor (Will.) Fink. POPE CO.: Lusk Creek Canyon, 4076. On white oaks and other trees in upland woods.

Caloplaca lobulata (Flörke) Hellb. JOHNSON CO.: Cave Creek Hill Prairie, 6800. On sandstone.

Caloplaca oxfordensis Fink. RANDOLPH CO.: Piney Creek Ravine, 795. On sandstone near a creek.

Chaenotheca ferruginea (Turn. ex Sm.) Mig. JOHNSON CO.: Cedar Falls, 6802. On Juniperus in dry woods.

Cladonia brevis (Sandst.) Sandst. POPE CO.: Lusk Creek Canyon, 3627. Common on sandstone bluff tops and in old fields.

Cladonia caroliniana Schwein. ex Tuck. POPE CO.: Lusk Creek Canyon, 4140. On sandstone bluffs, often with C. uncialis.

Cladonia pityrea (Flörke) Fr. POPE CO.: Lusk Creek Canyon, 5416. On the bark of Ulmus alata on a sandstone bluff.

Cladonia strepsilis (Ach.) Vain. RANDOLPH CO.: Piney Creek Ravine, 6075. On sandstone.

Collema coccophorum Tuck. UNION CO.: Pine Hills, 5451. On soil over limestone.

Collema furfuraceum (Arn.) Du Rietz. JACKSON CO.: Grand Canyon, 3873. On trees in dry to mesic woods.

Heterodermia domingensis (Ach.) Trev. ALEXANDER CO.: Horseshoe Lake, 4154. On Liriodendron at the edge of a low woods; this is a southeastern species.

Heterodermia echinata (Tayl.) W. Culb. JOHNSON CO.: Cedar Bluff, Earle 3091. On Juniperus. This is the only known collection of this species in Illinois.

Lecania nylanderiana Mass. UNION CO.: Pine Hills, 4065. On limestone on a bluff top.

Lecanora caesiocinerea Nyl. UNION CO,: Pine Hills, 481. On limestone on a dry slope.

Lecanora campestris (Schaer.) Hue. JOHNSON CO.: Cave Creek Hill Prairie, 6240. On calcareous sandstone.

Lecanora deplanans Nyl. UNION CO.: Cobden, Earle 2959. On sandstone.

Lecanora versicolor (Pers.) Ach. JOHNSON CO.: Cave Creek Hill Prairie, 7506. On calcareous sandstone.

Lecidea aeruginosa Borr. POPE CO.: Lusk Creek Canyon, 5982. On wood on bluff tops.

Lecidea botryosa (Fr.) Th. Fr. POPE CO.: Lusk Creek Canyon, 6276. On wood on bluff tops.

Lecidea macrocarpa (DC.) Steud. POPE CO.: Lusk Creek Canyon, 557. On sandstone in sunny places.

Lepraria candelaris (L.) Fr. POPE CO.: Lusk Creek Canyon, 6834. On trees on a dry slope.

Lobaria quercizans Michx. GALLATIN CO.: Pounds Hollow, 6098. On Quercus and Ulmus in upland woods.

Microglaena muscorum (Fr.) Th. Fr. UNION CO.: Pine Hills, 3534. On moss on a dry slope.

Normandina pulchella (Borr.) Nyl. POPE CO.: Lusk Creek Canyon, 4077 (WIS). On Leptogium in a wooded ravine.

Opegrapha cinerea Chev. UNION CO.: Pine Hills, 731. On Carya.

Opegrapha lichenoides Pers. JOHNSON CO.: Cedar Falls, 2562. On Acer in mesic woods.

Parmelia austrosinensis Zahlbr. POPE CO.: One Horse Gap, 5415. On Juniperus on a bluff.

Parmelia hypomelaena Hale. SALINE CO.: Stoneface, 6460. On exposed sandstone.

Parmelia margaritata Hue. RANDOLPH CO.: Piney Creek Ravine, 5394. On a black oak in dry woods, rare.

Parmelia michauxiana Zahlbr. JACKSON CO.: Devil's Den, Skorepa & Rust, 6425. Common on trees (rarely sandstone) in dry places.

Parmelia piedmontensis Hale. SALINE CO.: Garden of the Gods, 5310. On exposed sandstone. Previously known from North Carolina and Tennessee (Hale, 1964).

Parmelia tasmanica Hook. f. & Tayl. RANDOLPH CO.: Piney Creek Ravine, 5360. On exposed sandstone.

Physcia halei Thoms. RANDOLPH CO.: Piney Creek Ravine, 4727. On exposed sandstone. This species also grows on chert at Pine Hills in Union County.

Physcia phaea (Tuck.) Thoms. UNION CO.: Pine Hills, 406. On limestone on a dry slope, rare.

Physcia pusilloides Zahlbr. JACKSON CO.: Grand Tower, 5389. On Populus.

Physcia subtilis Degel. UNION CO.: Pine Hills, 6070. On chert, often with P. halei and Rinodina spp.

Placynthium petersii (Nyl.) Burnh. POPE CO.: Copperous Branch Hill Prairie, 3698. This species and P. stenophyllum are typical of Hill Prairies in southern Illinois.

Placynthium stenophyllum (Tuck.) Fink. JOHNSON CO.: Cave Creek Hill Prairie, 5831. On calcareous rocks in the open.

Protoblastenia rupestris (Scop.) J. Stein. POPE CO.: Golconda, 6821. On limestone.

Pycnothelia papillaria (Ehrh.) Duf. RANDOLPH CO.: Piney Creek Ravine, 6072. On soil on a dry slope.

Rinodina kentuckyensis Fink. UNION CO.: Pine Hills, 407. On exposed chert.

Thyrea pulvinata (Schaer.) Mass. UNION CO.: Pine Hills, 709. On limestone on bluff tops.

Umbilicaria papulosa (Ach.) Nyl. SALINE CO.: Garden of the Gods, 6788. On a sandstone outcrop in dry woods; a few plants were on Quercus and Vaccinium. This is the only locality for this conspicuous lichen in Illinois. It grows in an area where it is in danger of being eliminated from the Illinois flora.

Verrucaria finkiana Serv. UNION CO.: Pine Hills, 512. On limestone.

Verrucaria virens Nyl. UNION CO.: Pine Hills, 714. On limestone.

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RESIDUES OF ORGANOCHLORINE INSECTICIDES IN FOX SQUIRRELS FROM SOUTH-CENTRAL ILLINOIS[1]

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ABSTRACT

Carcasses of 28 fox squirrels (Sciurus niger) collected from Fayette County in south-central Illinois in 1975 were analyzed for a variety of pesticides. Only 3 of the 28 fox squirrels contained dieldrin, whereas 25 of the 28 contained DDE. Both dieldrin and DDE residues occurred at low levels. Lactating fox squirrels showed higher average levels of DDE than other groups of squirrels.

INTRODUCTION

Fox squirrels (Sciurus niger) comprise approximately 74 percent of the Illinois squirrel population (Preno and Labisky 1971:36). Because squirrel hunting is a popular sport in Illinois, humans consume a substantial amount of squirrel meat. Therefore, an examination of the pesticide content in a sample of fox squirrels may have important ecological and informational implications.

METHODS

A sample of 28 fox squirrels was collected during the hunting season of 1975 from three large areas of timber in Fayette County in south-central Illinois. This sample of squirrels was separated into five groups: lactating adult females, nonlactating adult females, adult males, subadult females, and subadult males. The squirrels were eviscerated and the head, feet, and tail removed. The remaining carcass with hair was ground in a Hobart grinder until homogeneous.

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[1] A Contribution of Federal Aid Project W-66-R, the Illinois Natural History Survey, the Illinois Department of Conservation, and the U. S. Fish and Wildlife Service, cooperating.

Duplicate 25-g samples of each squirrel carcass were analyzed for pesticides and polychlorinated biphenyls (PCB's). The 25-g samples were weighed and then digested overnight in a solution of 25 ml of 50% KOH and 50 ml ethyl alcohol. The samples were then extracted in a 1,000-ml separatory funnel with 50 ml nanograde hexane. The hexane layer was washed three times with deionized water and drained through a Na_2SO_4 funnel to remove any remaining water. The hexane was then reduced under a Snyder column to a volume of 2 ml and rinsed through a 30-g florisil column. The florisil column was pre-eluted with 50 ml nanograde acetone, 50 ml ethyl ether, and 50 ml dry hexane to activate the florisil. After cleaning in the florisil column, the samples were reduced again under a three-ball Snyder column to approximately 5 ml. The samples were then adjusted to volumes suitable for gas chromatographic analyses.

The analyses were done on a Varian-aerograph Model 2100 Chromatograph with an electron capture detector utilizing radioactive Scandium foil. The glass column (15.24 x 0.64 cm) was packed with 3% OV-210 and 1.5% OV-17 coated on Chromosorb W 80-100 mesh. The column temperature was 200°C, detector 250°C, injector 210°C, with nitrogen as the carrier gas at 40 ml per minute. The samples were screened for aldrin, lindane, heptachlor, heptachlor epoxide, BHC's, chlordane, endrin, dieldrin, DDT, DDE, and the PCB's araclor 1242, 1248, and 1254. The lower limit of detectability for each substance was one ppb.

RESULTS AND DISCUSSION

The concentrations of pesticides found in the specimens were low. Only DDE, a metabolite of DDT, and dieldrin, a residue of aldrin, were detected. Only 3 (a nonlactating adult female, an adult male, and a subadult female) of the 28 squirrels contained dieldrin, and the range of dieldrin concentrations was 0.0005 to 0.0023 ppm [$\bar{X} = 0.0011 \pm 0.0006$ (SE)]. However, 25 of the 28 specimens contained DDE residues. The DDE concentrations ranged from 0.0008 to 0.0195 ppm, with a mean of 0.0041 ± 0.0007 (SE) for the 25 squirrels in which DDE was detected (Table 1). The highest concentration of DDE was found in the adult female lactating group, which had a mean value of 0.0053 ppm. The adult female nonlactating group had the lowest mean concentration, 0.0023 ppm. The remaining groups had concentrations approximating the mean concentration for all squirrels examined, 0.0037 ppm of DDE (Table 1). T-tests of the means yielded no significant differences in DDE concentrations among the groups. Such low concentrations of these insecticides probably present little danger to the fox squirrels themselves or to humans that consume squirrel meat with similar levels of insecticide residues.

Both DDE and dieldrin are extremely stable residues of insecticides that were used on Illinois croplands--primarily fields planted to corn. DDT was used in Illinois from the late 1940's until 1965 (Dr. Stevenson Moore III, Extension Entomologist, Illinois Natural History Survey, personal communication). Use of aldrin began in Illinois in 1953 and accounted for approximately half of all insecticide use in the late 1960's, after which it gradually declined to insignificant levels by 1976 (Illinois Cooperative Crop Reporting Service 1969-72, Moore et al. 1977, Dr. Stevenson Moore III, personal communication).

Table 1. Mean, standard error, and range of DDE residues in 28 fox squirrels[a] collected in Fayette County, Illinois, during August - October, 1975. Sample sizes are in parentheses.

Sex- and Age-Class	DDE Residues[b] (ppm)
Lactating adult females	0.0053 ± 0.0029 0.0 - 0.0195 (6)
Nonlactating adult females	0.0023 ± 0.0008 0.0 - 0.0050 (6)
Adult males	0.0038 ± 0.0006 0.0017 - 0.0050 (6)
Subadult females	0.0032 ± 0.0007 0.0009 - 0.0065 (8)
Subadult males	0.0048 ± 0.0002 0.0046 - 0.0050 (2)
Mean	0.0037 ± 0.0007 0.0 - 0.0195 (28)

[a] Whole carcasses except for viscera, head, feet, and tail.

[b] Wet weight.

Fayette County is moderately cultivated. Approximately 69 percent of the farm ground is planted to harvestable crops, with corn, soybeans, and wheat the major crops (Illinois Cooperative Crop Reporting Service 1976). Approximately 21 percent of Fayette County is forest land (Nixon et al. 1978). Thus, it is possible that fox squirrels living in areas of Illinois more intensively cultivated than Fayette County may have higher levels of DDE and dieldrin as well as residues of other pesticides.

Fox squirrels could take up DDE and dieldrin in various ways. They could acquire dieldrin through direct contact with treated soil (Moore et al. 1973). Squirrels could ingest treated soils voluntarily (Baumgartner 1939)

or accidentally while consuming mast that has been buried or other foods in close association with soil (for example, waste corn, fungi, and seeds). Wind erosion, especially in fall-plowed fields, can scatter treated soil to timbered areas. Insecticides can enter the water table through natural percolation or by washing from agricultural fields. Mast-producing trees could absorb water containing the insecticides and then store the insecticides in their seeds, where they become available to squirrels.

Young fox squirrels may receive insecticides from their mothers. Clark et al. (1975) found that DDE and dieldrin residues in young bats (Tadarida brasiliensis) were passed from adult females via placental transfer and nursing. Ottoboni and Ferguson (1969) found that lactating rats (Rattus norvegicus) had DDT concentrations in milk lipids up to 10 times higher than the levels of DDT in their feed. We discovered in this study that lactating fox squirrels had a higher average residue of DDE than any other group (Table 1). This higher DDE residue in lactating squirrels is probably associated with the higher fat content in reproductively active female fox squirrels (Havera 1978). Thus, in addition to obtaining DDE from their environment, fat-soluble DDE residues are probably passed maternally to some extent from generation to generation of squirrels.

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Dr. Stevenson Moore III, Extension Entomologist, Illinois Natural History Survey, provided valuable advice. Dr. G. C. Sanderson, Dr. W. R. Edwards, C. M. Nixon, and Helen C. Schultz, Illinois Natural History Survey, critically reviewed and edited the manuscript.

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NON-SAPONIFIABLE FRACTION OF TECOMELLA UNDULATA LEAVES

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Abstract.--The unsaponifiable matter from the petroleum ether extract of leaves of Tecomella undulata was fractionated and shown to consist of n-alkanes, n-octacosanol, sitosterol, stigmasterol, campesterol, and α-amyrin. Oleanolic acid was also obtained from the extract.

In India Tecomella undulata G (Don.) Seem (Bignoniaceae) has been used in the indigenous system of medicine for various ailments (Kirtikar and Basu, 1933, p. 1841). There is no earlier report regarding the chemical investigation of T. undulata leaves and seeds, but the heartwood (Gupta et al., 1969; Joshi and Singh, 1974), bark (Pandey and Das Gupta, 1970, 1971; Singh et al., 1972), and flowers (Taneja et al., 1975) have been examined. In this communication we report the results of our studies on the leaves of T. undulata.

METHODS AND RESULTS

General.--The plant material used in this investigation was collected in Chandigarh (India) during August-September and dried under shade at room temperature. Voucher specimens are stored at the Chandigarh, India, address. The material was reduced to a moderately coarse powder before extraction. The melting points were secured with a Townson and Mereer Ltd., England, apparatus and are corrected. Ir spectra were recorded on a Perkin-Elmer 137 spectrophotometer, nmr on a Varian A-60D spectrometer on samples in $CDCl_3$ with Me_4Si as an internal standard, and mass spectra with a Hitachi RMU-6E mass spectrometer. GLC's were carried out on a Varian-Aerograph Series 2700 instrument with flame ionization detector and an Autolab System IV computing integrator. Except as indicated a 5 ft. x 1/8 in. column of 1.5% OV-101 on 100/120 HP Chrom G was utilized.

Fractionation of petroleum ether extract.--Leaf powder (1.6 kg) was extracted with petroleum ether (60°-80°) in a Soxhlet apparatus. During the extraction a granular solid (16 g) deposited and was collected, then the filtrate was concentrated to an oily viscous mass (51 g).

The residue (51 g) was saponified by refluxing with 0.5 N ethanolic potassium hydroxide (500 ml), and the unsaponifiable portion (22 g) was

recovered according to the procedure outlined in British Pharmacopoeia (1973, p. A85). The unsaponifiable fraction was chromatographed over alumina (S. Merck, India, 410 g), and elution was begun with petroleum ether-benzene (2:1). The first few fractions (3 x 150 ml) yielded a wax (6.7 g) which was purified by passing through a alumina column with petroleum ether to give a white amorphous residue, mp 60-62° (fraction A).

Later fractions (11 x 150 ml) yielded a residue (1.7 g) which gave crystals from acetone with mp 81-82° (fraction B). Further elution with petroleum ether-benzene (1:1; 15 x 150 ml) gave 1.2 g, which was crystallized from methanol; mp 129-132° (fraction C). The residue (0.80 g) from eluates obtained with benzene-chloroform (1:1; 4 x 150 ml) had mp 182-185° (from acetone-petroleum ether; fraction D).

The granular solid (16 g) obtained above was dissolved in hot petroleum ether-benzene (4:7). An amorphous residue (6 g) again resulted and was collected. It was converted into an acetate by heating with acetic anhydride-pyridine for 2 hr. on a steam bath. The contents were cooled and poured into water. The separated solid was collected, washed with water, dried, and recrystallized from methanol to yield fraction E, mp 262-264°.

Study of fractions A, B, C, D, and E.--Spectral examination of fraction A showed ν_{max} typical alkane bands. TLC on silica gel with petroleum ether gave a single spot. GLC analysis, linear temperature program of 90 to 240°, showed peaks corresponding to the following n-alkanes: C_{27}(3.1)%), C_{28}(1.2%), C_{29}(17.0%), C_{30}(2.6%), C_{31}(28.8%), C_{32}(3.8%), C_{33}(33.5%), C_{34}(3.1%) and C_{35}(6.9%), which were correlated to authentic n-alkanes (Applied Science Labs, State College, Pa.)

Fraction B had ν_{max} (KBr) 3308 cm^{-1} (O-H) and 733, 722 cm^{-1} [-$(CH_2)_x$-]; no uv absorption; nmr, δ 0.87 (br t, J=5 Hz, -CH_2-CH_3), 1.26 [s,-$(CH_2)_x$-] and 3.68 (t, J=6 Hz, -CH_2-CH_2-OH). TLC on silica gel with benzene-ether (3:2) gave a single spot; while GLC 235° exhibited a single peak identical to n-octacosanol (identical in retention time with an authentic sample; K+K Labs, Plainview, N. Y.)

Anal: Calcd. for $C_{28}H_{58}O$: C, 81.87; H, 14.23. Found: C, 82.18; H, 14.42.

Examination of fraction C revealed ir (KBr) bands at 3390 cm^{-1} (O-H) and 966 cm^{-1} (trans-disubstituted double bond); uv, end absorption only; nmr, similar to sitosterol. TLC on silica gel with benzene-ether (7:3) gave a single spot; but GLC at 240° indicated a mixture of sitosterol (79.2%), stigmasterol (19.1%), and campesterol (1.7%).

Fraction D had ir (KBr) bands identical to α-amyrin; nmr signals at δ 5.20 (CH=C) and at δ 0.81, 0.93, 1.02, and 1.09 (-C-CH_3). TLC on silica gel with benzene-ether (1:1) gave a single spot. GLC of its trimethylsilyl ether derivative on a 6 ft x 1/8 in. column of 3% SE-30 on Chromosorb W at 235° gave a single peak identical to silylated authentic α-amyrin (Pfaltz and Bauer, New York).

Fraction E:$[\alpha]_D$ + 74° (c 0.6, CHl_3); ν_{max} (KBr) 3210 cm^{-1} (O-OH), 1730 cm^{-1} (C=O, ester), 1680 cm^{-1} (C=O, acid), 1255 cm^{-1}; no uv absorption; nmr, δ 2.02 (-OOC-CH_3), δ 5.25 (t, J-4 Hz, vinylic proton at C-12), 4.48 (m, 3α-H), 0.73, 0.83, 0.88, 0.90, 0.91 and 1.10 (-C-CH_3); m/e 438 (6%), 248 (100%), 203 (33%) and 133 (12%).

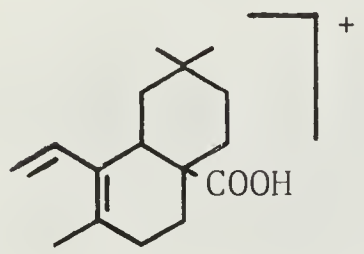
Anal.: Calcd. for $C_{32}H_{50}O$: C, 77.06; H, 10.11. Found: C, 77.61; H, 10.30.

The mp of fraction E showed no depression on a mixture with authentic oleanolic acid acetate and its ir spectrum was identical to that of oleanolic acid acetate.

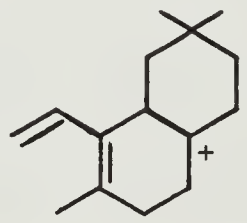
DISCUSSION

Chromatography of the unsaponifiable matter from the petroleum ether extract, after removal of a grandular solid, yielded four main materials which gave single spots on TLC. The first, however, proved to be an n-alkane mixture of C_{27} through C_{35} with C_{29}, C_{31}, and C_{33} predominating. The second was found, interestingly, to be only n-octacosanol without any accompanying homologs, while a sterol mixture of sitosterol, stigmasterol, and campesterol composed the third. The last main compound was readily identified as the pentacyclic triterpene α-amyrin.

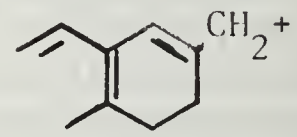
The solid which deposited was acetylated and purified by recrystallization to yield a substance which had nmr signals for a vinylic proton at δ 5.25 and acetate protons at δ 2.02. Also, signals for seven C-methyls appeared. A mass spectrum had peaks at m/e 438 (M^+-CH_3COOH), 248, 203, and 133. The peak at m/e 248 is a characteristic fragment[3] (a) produced by



(a)



(b)



(c)

retro-Diels-Alder reaction in ring C of a pentacyclic triterpene and is suggestive of a C-12 double bond (Budzikiewicz et al., 1963). The peaks at m/e 203 and 133 are due to fragments (b) and (c), respectively. On the basis of the data the solid was identified as oleanolic acid acetate.

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MOUSE REPRODUCTION IN HELIUM-OXYGEN

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ABSTRACT: Two controlled atmosphere chambers constructed to maintain 80% helium-20% oxygen and air (80% nitrogen-20% oxygen) atmospheres were used to test groups of mice (three females and one male each), all of which were proven parents. Survival of offspring was 20/37 in He-O_2 and 10/38 in air. This demonstrates that it is possible for mice to reproduce in the He-O_2 atmosphere.

INTRODUCTION

Current literature indicates that development of a variety of different organisms is possible in a helium-oxygen atmosphere (Boriskin, et al., 1962, Latterell, 1966, Weiss, et al., 1965, 1972, Ferguson, et al., 1973). Effects of helium, or the absence of nitrogen, on reproduction in mammals is of concern because of increased use of helium-oxygen atmospheres for life support systems in space and undersea environments. The unavailability of information concerning mammalian reproduction in helium-oxygen atmosphere prompted this study. It establishes that mice can conceive and raise litters in a He-O_2 atmosphere.

MATERIALS AND METHODS

Albino mice (CLC strain) were obtained from Scientific Small Animal Supply, Arlington Heights, Illinois. Two environmental chambers were constructed to hold the desired atmospheres, 80% helium-20% oxygen in one and air in the other. These chambers were designed to maintain constant temperature ($27° \pm 1$), regulate diurnal light conditions (12 hours light/12 hours dark), and maintain relative humidity within 50-80% as measured by hair hygrometers. Atmospheric pressure inside the chambers was kept at 13 mm positive water pressure by a weighted spirometer to insure that leaks would be outboard.

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Nitrogen contamination in the He-O_2 chamber was determined by use of a sound resonance tube (Dublin et al., 1939). Contamination was kept to 3% or less by a continuous flow of helium-oxygen mixture (250 cc/min). A similar flow of air was maintained through the air chamber. Oxygen and carbon dioxide levels were determined for each chamber every 12 hours using a modified Scholander apparatus and the chamber levels of these gases were adjusted to conform with those of a normal atmosphere (Scholander, 1942). Carbon dioxide, ammonia and excess humidity were removed by pumping the chamber gases through indicator soda lime, boric acid crystals, and calcium chloride. Diet consisted of Purina Lab Chow for Rats and Mice and water ad libitum with no supplements. Litter changes were made once a week without opening the chamber. Cages were acrylic plastic, 30 x 15 x 8.5 cm high (inside). A system of locks and the use of dry box gloves prevented atmospheric contamination of both chambers. Each chamber was started with one male and three females. All animals were proven parents.

RESULTS AND DISCUSSION

The sexes were kept separated for one day following entry into the chambers. Subsequent recordings of birth dates indicated the first effective matings all occurred between 2½ and 7 days. No attempt was made to monitor reproductive physiology and no postmortem examinations were made. One female in each chamber ate her first litter. Both were remated within a few days and produced new litters. Thus both males were able to produce sperm and to copulate, both females were able to ovulate and conceive after at least 23 days in the chambers. Table 1 provides data on the eight litters observed. Female #2 in the He-O_2 chamber had also eaten the litters she had produced before being placed in the chamber and thus showed no change from her behavior in air.

TABLE 1

Parent Litter		Number Born	Survived 60 days	Comment
He-O_2 Chamber				
1		9	9	
2	A	8	0	eaten
	B	8	0	eaten
3		12	11	
He-O_2 Total		37	20	
Air				
4		6	0	poor nest
5	A	11	0	eaten
	B	9	5	poor nest
6		12	5	
Air Total		38	10	

Reproduction proceeded normally and litter sizes were within the normal range (8-12) for both chambers. Thirty seven mice were born in the helium-oxygen mixture and thirty-eight in the air; of these twenty survived in helium-oxygen and ten in air. No obviously abnormal mice were born in either chamber and sex ratios were normal. Normal growth and weight gain did not occur in either chamber. Stunting was evident to different degrees in both chambers even though individuals of any one litter tended to remain the same size as their respective littermates. There was a noticeable difference in litter weights and size among the different litters of both chambers. Sexual maturity, as evidenced by sexual activity, descended testes and aggressive behavior on the part of the males, did not occur among offspring in either chamber. One sixty day old litter was removed from each of the chambers and weight recorded for twenty days. At the end of this period an average individual gain of approximately one gram was noted, indicating that the stunting was a permanent feature. Because of the failure of sexual maturation no second generation offspring were obtained in either chamber. Deleterious effects were similar in both chambers and can not be separately attributed to either He-O_2 or air.

The effects of the chamber environment seemed subjectively to have been more serious in air than in He-O_2. Only one mouse died in the He-O_2 chamber (other than by cannibalism). Seventeen mice died in the air chamber during the same period. It seems possible that some of this difference was due to the 6½ fold difference in thermal conductivity in the He-O_2 as compared to air. Mice in the He-O_2 atmosphere appeared comfortable at 27°C whereas by comparison the mice in air showed abnormal behavior, including poor nest building, lethargy, haphazard excretory habits, and ungroomed, untidy appearance When samples of the atmospheres were tested by smell, both exhibited ammonia and other noxious odors. Chronic exposure to relatively low levels of ammonia is known to cause a variety of pathological changes in mice and other mammals and birds (Mikhaylov, 1965). Thus the ammonia alone could have been sufficient to induce the observed stunting. It seems possible that gases from decomposing fecal material, food, plastic cages, or the paint used in the chambers may all have contributed to stunting and/or abnormal behavior. The ventilation fans produced a continuous whine which may have had deleterious effects.

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THREE NEW SCUTELLEROID STATE RECORDS FOR ILLINOIS (HEMIPTERA)

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ABSTRACT. -- The first records in Illinois of 3 scutelleroid species are reported.

During the past year (1977), I have had the opportunity to examine scutelleroid collections from various institutions in Illinois. I have discovered 3 new records based on specimens housed in the Department of Biological Sciences, Illinois State University, Normal, and Illinois Natural History Survey, Urbana, collections. Below is presented the information on these specimens.

Family Corimelaenidae

Genus *Corimelaena* White

Corimelaena (*Corimelaena*) *alpina* (McAtee & Malloch). This rare negro bug was described in 1933 from specimens collected on top of Whiteface Mountain, New York. Since that time, no further distribution records have been published. However, Dr. R. I. Sailer, University of Florida, Gainesville, mentioned in an unpublished manuscript that he determined specimens of *C. alpina* from Minnesota.

The Illinois Natural History Survey collection contains an adult ♀ specimen of *C. alpina* labeled Northern Illinois, Andreas Bolter Collection. Based on Sailer's manuscript, the occurrence of this species in the northern part of the state is not surprising.

Family Pentatomidae

Subfamily Acanthosominae (Stål)

This subfamily is represented in North America by 4 species, only one of which [*Elasmostethus cruciatus* (Say)] has been reported previously from Illinois (Hart 1919).

Genus *Elasmucha* Stål (=*Meadorus* Mulsant & Rey)

Elasmucha lateralis (Say). This species ranges from Quebec and New England

west to the Pacific (Blatchley 1926), and has been collected on beech and birch trees (Frost and Haber 1944, Torre-Bueno 1939), and vegetation in or by water (Stoner 1922).

An adult ♂ specimen, collected in Mason County, is housed in the Illinois State University collection with the following label information: Mason State Park, Illinois, 16 Oct. 1971, P.S. Buck, Coll.

Genus *Elasmostethus* Fieber

Elasmostethus atricornis (Van Duzee). This species has been reported from Montreal, Canada, New York, Maryland, Indiana (Blatchley 1926), Ohio (Furth 1974), and Michigan (McPherson 1970), and collected on stems and leaves of *Aralia racemosa* L. (Blatchley 1926).

Six adult specimens of this insect are housed in the Illinois Natural History Survey collection with the following label information minus county names:

Carroll Co., Savanna, 17 July 1957, 1 ♀ , Ross & Bouseman, Coll.
Lake Co., Volo, 12 Aug. 1937, 1 ♂ , Ross & Burks, Coll.
La Salle Co., Starved Rock, 3 Sept. 1930, 2 ♂ , 2 ♀ , T. H. Frison, Coll.

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I wish to thank Dr. E. L. Mockford, Illinois State University, and Mr. D. W. Webb, Illinois Natural History Survey, for allowing me to examine the scutelleroid collection of their respective institutions.

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CYCLOCOELUM MUTABILE (ZEDER 1800) DUBOIS 1959 (TREMATODA: CYCLOCOELIDAE) IN FULICA AMERICANA (GMELIN) FROM SOUTHERN ILLINOIS

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ABSTRACT

Four specimens of Cyclocoelum mutabile (Zeder 1800) Dubois 1959 were found in the air sacs of 2 of 5 American coots, Fulica americana (Gmelin) collected during the summer of 1975 in Williamson County, southern Illinois. This constitutes the first report of this fluke in F. americana from Illinois.

Cyclocoelum mutabile (Zeder 1800) Dubois 1959 (syn. C. pseudomicrostomum Harrah 1922 and C. microcotyleum Noble 1933) is a cosmopolitan fluke occurring in the air sacs of several species of gruiform birds. It has been reported on at least two occasions in American coots, Fulica americana (Gmelin), from their summer breeding grounds in Canada and more frequently from their wintering habitat throughout the southern region of the contiguous United States.

The most extensive survey of C. mutabile in F. americana was that conducted by Colbo (1965) who examined 371 coots on their summer breeding grounds in northern Alberta. Other reports of this parasite from American coots in North America include those of Harrah (1922), Noble (1933), Roudabush (1942), Taft (1971), Kinsella (1973) and McLaughlin(1976).

Studies on the life cycle of this fluke were initiated by Wootton (1964) with complete elucidation by McLaughlin (1976). Miracidia of C. mutabile, each containing a single redia, were infective to six species of snails: Helisoma trivolvis (Carpenter), Gyralus circumstriatus (Tyron), Promenetus exacuous (Say), Armiger crista (L.), Physa gyrina (Say), and Lymnaea elodes (Say). Cercariae encyst as metacercariae in the tissues of the same snail between 2 and 3 weeks after exposure. Metacercariae were infective to coots,

F. americana, and mature worms were recovered from the air sacs 30 days after exposure.

In the course of parasitological examination of birds from different habitats in southern Illinois, 4 flukes of the genus Cyclocoelum were found in the air sacs of 2 of 5 American coots collected during the summer of 1975 in Williamson County, southern Illinois. These specimens agree with the description of C. mutabile as described by Dubois (1959) and show no significant differences in the values established for that species. This represents the first report of C. mutabile in F. americana from Illinois.

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A TECHNIQUE FOR UNCOILING IMPROPERLY FIXED TAPEWORMS

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ABSTRACT

A procedure for efficient uncoiling of small weakly muscled, improperly fixed tapeworms is reported.

Because of the nature of some parasitological investigations, recovery of tapeworms *in situ* by autopsy from the host shortly after capture is not always feasible. The survey of a host for parasites may often be a part of a larger investigation such as a study of the food content wherein the field procedure involves the transfer of the entire gut and its contents to a container of alcohol or formalin. It is well known that this type of treatment results in twisted or coiled specimens rendering them difficult to study. A procedure for efficient uncoiling of small weakly muscled tapeworms was developed, the details of which are described herein. It is important to note that this technique is not intended for the uncoiling of large heavy muscled specimens.

Distorted specimens should be stained by standard parasitological procedures and no attempt made to uncoil them until they have been destained and transferred to 70% ethanol. It is at this point in the dehydration process that specimens should be straightened. A single tapeworm is transferred to a glass slide and a capillary tube placed on top of a proglottid that is in contact with the slide so that the tube is at a right angle to the longitudinal axis of the strobila. This process is continued as the worm is uncoiled resulting in a specimen that is completely covered with capillary tubes. The weight of the tubes is sufficient to prevent uncoiling. It is important that the specimen be constantly flooded with alcohol to prevent drying.

A glass slide is then placed on top of the series of capillary tubes and the entire preparation transferred to a large Petri dish or other suitable container. The specimen is dehydrated through the alcohols in this position. Since

only a portion of the specimen is exposed to the alcohols used in dehydration, the time normally allowed in each solution should be approximately doubled. After a suitable period in 95% ethanol, the top slide and capillary tubes can be removed and the specimen transferred to a smaller dish containing absolute alcohol. Two changes in absolute alcohol are necessary before clearing and mounting of the specimen for study.

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FALCAUSTRA MASCULA (RUDOLPHI 1819) (NEMATODA: KATHLANIIDAE) FROM AMBYSTOMA TIGRINUM (GREEN 1825) IN NEBRASKA

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ABSTRACT

A tiger salamander, Ambystoma tigrinum, from Nebraska was found to harbor the nematode Falcaustra mascula. This constitutes a new distributional record.

A tiger salamander, Ambystoma tigrinum (Green 1825), collected by R.L. Buckner, October 1973, in Boone County, Nebraska, was found to be infected with 2 male and 7 female nematodes of the genus Falcaustra. Measurements and morphology of the Nebraska specimens correspond with the description of Falcaustra mascula (Rudolphi 1819) Freitas and Lent 1941 as given by Lent et al (1946). This species, first described from specimens found in a Brazilian colubrid snake, has also been found in other Brazilian colubrid snakes as well as hylid and leptodactylid frogs, and in Paraguayan bufonid and leptodactylid anurans (Lent et al, 1946; Walton, 1964; Gomes and Vicente, 1966). This nematode was reported for the first time from salamanders Ambystoma tigrinum, Rhyacosiredon altamirana (Dugès 1895), R. leorae Taylor 1943 and R. rivularis Taylor 1940 and for the first time in Mexico by Dyer and Brandon (1973). Later that same year, these authors reported F. mascula from A. tigrinum in Oklahoma, representing the first report of this parasite in an amphibian host in the contiguous United States. The present report extends the northern geographical range of F. mascula in A. tigrinum to Nebraska.

While the literature on helminth parasites of amphibians in the contiguous United States is extensive, the majority of reports are confined primarily to the parasites of anurans. It is therefore quite possible that F. mascula occurs in several salamanders and ranges over several states in this region.

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AN ANOMALOUS SUPERIOR MESENTERIC ARTERY IN FELIS DOMESTICA

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ABSTRACT: An anomalous origin of the superior mesenteric artery in the domestic cat is reported.

In the cat, shortly caudad to the diaphragm the dorsal aorta gives rise to two large visceral arteries. The more cephalic is the coeliac artery passing toward the stomach. Soon it divides into three branches. The most cranial one is the hepatic artery passing along the dorsal side of the lesser curvature of the stomach and entering the lesser omentum. The next branch is the left gastric artery passing to the lesser curvature of the stomach. The most caudal branch is the splenic artery. It is the largest of the three and courses in the greater omentum towards the spleen. The more caudad of the large visceral arteries is the superior mesenteric. This artery extends out through the mesentery where it fans out into a large number of branches supplying the small and part of the large intestine (Fig.1).

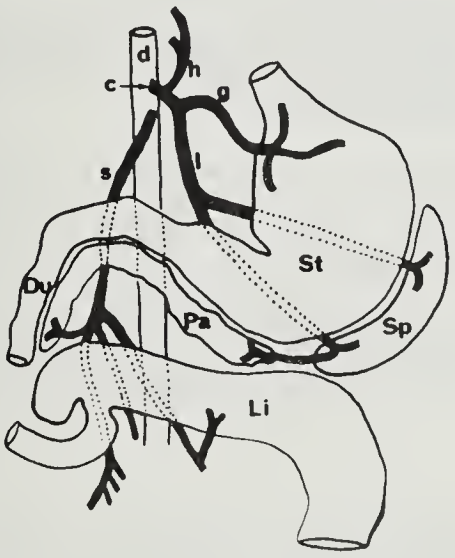

Fig. 1. The usual distribution of the coeliac and superior mesenteric arteries in the cat. Explanation of symbols: Du, duodenum; Li, large intestine; Pa, pancreas; Sp spleen; St, stomach; c, coeliac artery; d, dorsal aorta; g left gastric artery; h, hepatic artery; l, splenic artery; s, superior mesenteric artery.

A dissection in developmental anatomy class revealed an anomalous origin of the superior mesenteric artery as well as the major branching of the coeliac artery in a female cat.

In this specimen the coeliac artery gives rise to the superior mesenteric artery 1.5 cm distal to its origin at the dorsal aorta. The coeliac then courses another 0.4 cm towards the stomach before giving rise to the large splenic artery. After another 0.2 cm the coeliac forks into the hepatic and left gastric arteries (Fig.2). The branches of all these arteries have normal distribution.

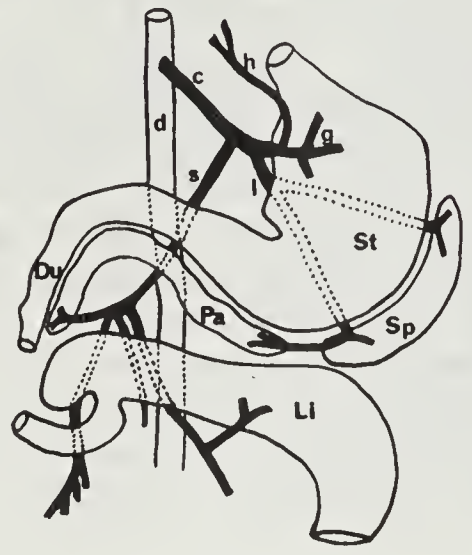

Fig. 2. Anomalous superior mesenteric artery. For explanation of symbols, see Fig. 1.

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AN UNUSUALLY LATE RECORD OF THE MEADOW JUMPING MOUSE (*Zapus hudsonius*) IN NORTHWESTERN ILLINOIS

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ABSTRACT

The latest recorded capture of an active Meadow Jumping Mouse (*Zapus hudsonius*) on November 21, 1971 is reported.

According to Whitaker (1963) and Whitaker and Mumford (1971), the Meadow Jumping Mouse (*Zapus hudsonius*) enters hibernation in October or early November. The two latest recorded captures of active specimens were by Hamilton (1935) near Ithaca, N.Y., 42° 25'N on November 18 and Whitaker and Mumford (1971) in Carrol Co., Indiana, 40° 30'N on November 20.

During 2,000 trap nights extending from October 30 - December 6, 1971, we captured a single female (TL., 192 mm; T. 113 mm; H.F., 27 mm; E. 12 mm; wt. 23.1 g) on November 21, along the right-of-way of Interstate Highway 80 in Henry County, IL. (9 mi. N, Cambridge, 41° 31'N). The site of capture was dominated by tall blue grass, brome grass and a few scattered herbaceous plants which had not been mowed for at least two years.

The specimen, prepared and placed in the Museum of Natural History, University of Kansas (K.U. 27252), showed an extensive subcutaneous fat layer indicative of imminent hibernation (Whitaker, 1963).

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